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SHRP-LTPP International Participation: Five-Year Report

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Abstract

This book is a compilation of reports submitted by Australia, Austria, Canada, Denmark, Finland, France, India, Japan, The Netherlands, Norway, Poland, Slovenia, Sweden, Switzerland, and the United Kingdom about their involvement with SHRP's Long-Term Pavement Performance (LTPP) program. These reports describe the varieties of international cooperation with SHRP-LTPP. Appendices note the people involved in the program and SHRP's research design.

Introduction

The Strategic Highway Research Program (SHRP) was a five-year, $150 million research program funded by a set-aside of state-apportioned federal highway aid funds. Congress authorized SHRP under section 128 of the Surface Transportation and Uniform Relocation Assistance Act of 1987 in response to the recommendations of state highway officials, industry representatives, and researchers (Strategic Transportation Research Study, 1984).

SHRP concentrated on a short list of high-yield activities where even modest technological progress could produce savings many times in excess of the research costs. The targeted research areas were Asphalt, Concrete and Structures, Highway Operations, and Long-Term Pavement Performance (LTPP).

The objectives of SHRP-LTPP were: to evaluate existing design methods; to develop improved design methods and strategies for rehabilitating existing pavements; to develop improved design equations for new and reconstructed pavements; to determine the effects on pavement performance of design, materials, construction, loading, environment, and maintenance; and to establish a national database of pavement inventory and performance information.

Beginnings of International Cooperation

International interest in SHRP developed at the outset of the program. This interest led to the convening of a SHRP International Workshop in 1986. Later that year, SHRP's Executive Committee adopted a policy of active international cooperation.

TRB Annual Meeting and SHRP International Workshop

A SHRP reception for international attendees was held at the annual meeting of the Transportation Research Board (TRB) in 1986. International interest in SHRP was confirmed by a special SHRP International Workshop in May 1986. Twenty-nine representatives from sixteen countries came to Alexandria, Virginia to discuss the program and future international cooperation between SHRP and the international community. This enthusiasm for SHRP led SHRP's Executive Committee to adopt a policy for international cooperation at its meeting in September 1986.

In February 1987, twenty-six countries and five international organizations were invited to participate in international cooperation with SHRP. By August 1987, fifteen countries had responded and fourteen had designated national coordinators. The coordinator acts as liaison

between that country's highway department and SHRP. The coordinator receives mailings from the Washington DC office for distribution and is responsible for reporting the status of that country's research to SHRP.

TRB/VTI Conference on Road Research

In September 1987 the Swedish Road and Traffic Research Institute (VTI) and TRB held a conference on present and future road research, with special emphasis on SHRP and highway safety research. The SHRP portion of the conference included separate sessions on SHRP's four research areas: Asphalt, Highway Operations, Concrete and Structures, and LTPP. About three hundred people from seventeen countries participated in the conference.

SHRP International Technical Workshop

In 1988, the SHRP Executive Committee approved a proposal for the first SHRP International Technical Workshop, which was held in Bath, England on September 14, 1988. Sixteen countries (two-thirds of the SHRP cooperating countries at that time) were represented. Emphasis was placed on information exchange with a significant amount of time allocated to round table discussions. The workshop had two themes: LTPP and Concrete and Structures.

The LTPP portion of the workshop involved presentations and discussions on implementation of SHRP's data collection procedures in the various countries planning to establish parallel and complementary General Pavement Study (GPS) and Specific Pavement Study (SPS) sites. Twenty-seven delegates representing seventeen countries attended. Prior to the workshop, four papers were mailed to the international community in order to give the participants background information on the SHRP-LTPP research study. The titles of the papers were:

- LTPP Past Activities
- LTPP Current Status
- LTPP Planned Activities
- International Participation in LTPP

Several countries presented their plans for their LTPP studies, which led to a discussion session which addressed problems such as definitions, units of measure, manuals and testing procedures, weigh-in-motion equipment, information management systems, laboratory accreditation, traffic, subgrade classification, and section length.

The Concrete and Structures portion of the workshop covered SHRP research on evaluation and rehabilitation of reinforced concrete bridges suffering from salt-induced corrosion of the reinforced steel. Sixteen delegates representing ten countries attended. During the workshop the results of an international questionnaire on bridge corrosion were presented. All eleven countries that responded reported some corrosion problems on their concrete bridges,

whether from deicing salt or sea salt, and whether on the decks (United States and Canada) or structures. An extensive discussion was held on the SHRP contracting plan and a list of researchers in other countries was compiled. The similarity and difference of corrosion problems in different parts of the world was a subject of discussion as well as different approaches to solving the problem.

SHRP and Traffic Safety on Two Continents

In September 1989, TRB and VTI held their second jointly organized conference in Gothenburg, on SHRP and Traffic Safety on Two Continents. Prior to the conference, a special International Long-Term Pavement Performance workshop was held to show the representatives the different levels of participation for overseas countries in the program. The SHRP staff presented a status report on the LTPP activities. This report discussed the experimental design principles, data collection, and data analysis. The delegates were shown how to use the Information Management System (IMS) and how it could be incorporated into overseas LTTP studies. Approximately thirty representatives from sixteen countries participated.

Continuing International Cooperation

Midcourse Assessment Meeting

SHRP's Midcourse Assessment Meeting was held August 1-3, 1990 in Denver, Colorado. The workshop included a brief session for international attendees with approximately forty participants from fourteen countries. Attendees were given a brief update on the midcourse status of the international participation. This was followed by three presentations by the SHRP staff outlining some of the areas where international participation or involvement was needed. The presentations and subsequent discussion at the workshop renewed interest in the LTPP study, especially in the SPS experiment. Several countries expressed an interest in participating with test sites from their construction programs, including rehabilitation of existing roadways (SPS-5 or SPS-6) as well as construction of new pavements (SPS-1 or SPS-2). SHRP welcomed this initiative, emphasizing that SPS sites provide:

- a means for evaluation of experimental features;
- incentive to establish a database to compare similar information developed in other countries; and
- information that adds to the state of the art for global researchers.

The results of the workshop were published in *Making the Most of the Second Half of SHRP: Proceedings of the SHRP Midcourse Assessment Meeting* (SHRP, 1990). This document summarizes the major conclusions and recommendations of the meeting. Included in the appendix of the report are:

- a list of advance and presentation of papers;
- a roster of the Executive Committee, Advisory Committees, and State Coordinators;
- a copy of the meeting agenda; and
- a list of participants.

International SHRP Workshop

Thirty participants representing twelve countries attended an international SHRP workshop held September 1990 in London before the International SHRP/Institution of Civil Engineers Conference entitled "Sharing the Benefits". The workshop's objectives were:

- to identify opportunities to participate in or run parallel research to SHRP's Asphalt, Highway Operations and Concrete and Structures research programs;
- to provide an update of international SHRP-related activity;
- to discuss issues to be addressed by participating countries that proceed with LTPP studies; and
- to discuss ways of maximizing the benefits of international cooperation in SHRP and related activities.

Following an overview of international activity, summaries of the activity in the Asphalt, Concrete and Structures, and Highway Operations programs were given. It was emphasized that several opportunities existed for international participation in these program areas.

International LTPP experiments were presented by five countries that had committed to establish LTPP test sections. The discussions after these presentations examined several issues including the possibility of integrating existing databases, establishing an international database, and developing a European database.

International data handling also was addressed at this workshop. Discussion of potential difficulties requiring resolution before transfer of data to SHRP's National Information Management System (NIMS) resulted in the following recommendations:

- Any country that modifies its copy of the IMS should contact SHRP and forward full documentation of any modification made.
- SHRP should tabulate other existing long-term studies and provide this data to anyone seeking to extract data from the SHRP database.
- SHRP should develop a policy ensuring the quality of all data forwarded by participating countries.

Conformance with ISO 9000 on quality assurance was also recommended.

Other issues discussed during the workshop were data extraction and conditioning monitoring, two highly important matters to such a joint research program. The international community requested that a register be kept of people requesting data and their anticipated use of the data in order to share their experiences with data analysis.

Concluding remarks from this workshop were that the discussions during the workshop had drawn the participants closer to meeting the objectives.

The International SHRP/Institution of Civil Engineers, ICE (UK) Conference in London, "Sharing the Benefits"

The International SHRP/Institution of Civil Engineers, ICE (UK) Conference in London, "Sharing the Benefits", held in October 1990, drew over 200 delegates to discussions of worldwide research. The opening session provided an overview and introduction to SHRP and the importance of international cooperation. Technical sessions were held in each of the four program areas of SHRP. Each technical session was followed by a half-day workshop, where the following four questions were discussed:

- What problems are SHRP likely to solve, and what problems will remain?
- What parallel or complimentary research is taking place elsewhere?
- What is being done to encourage implementation of SHRP research results in the United States?
- What might be done to increase the international benefits from the SHRP program?

The conference proved to be beneficial in clarifying the focused nature of the SHRP program. It identified other research relevant to the subjects covered by SHRP and some of the steps which might be taken by other countries to extend SHRP research to cover their particular circumstances. Additionally, it highlighted some of the differences in highway practices between the U.S. and other countries which need to be considered when evaluating SHRP results. The Institution of Civil Engineers published the proceedings of the conference.

LTPP International IMS Workshop

An LTPP International IMS (I-IMS) workshop was held in conjunction with the annual TRB meeting in January 1991. Coordinators and/or representatives from Australia, Canada, Denmark, Japan and the Netherlands, together with SHRP loaned staff from Australia, Sweden and Venezuela and representatives from FHWA, participated in the workshop. The workshop was a follow-up to the International SHRP workshop in London of October 1991. The general objectives of the workshop were:

- to answer any questions on the establishing or operating an I-IMS;
- to provide hands-on computer experience with the IMS;
- to provide an update on the status of the NIMS; and
- to discuss the establishment of the link between the NIMS and the I-IMS.

Presentations included update on the status of the NIMS, news of the first data release to the public, how to request data from the NIMS, an update on the status of the traffic database, discussion of quality assurance in the NIMS, and the plans for entering data from I-IMS to the NIMS. The use of the IMS was demonstrated by showing data entry, editing, data extraction, report generation, creating new tables, and modifying existing tables.

A significant outcome of the workshop was the call for a plan for conversions of units as a first step in the international data transfer process.

LTPP Traffic Data Collection Workshop

SHRP's LTPP Traffic Data Collection Workshop, held in Gothenburg, Sweden in September 1991, focused mainly on establishing traffic data collection and processing guidelines for international participants in the LTPP program. The potential of data collection, equipment availability and subsequent processing was discussed.

The full-day workshop stressed the need for "traffic data compatibility", especially concerning equivalent single axle loads (ESALs) which are needed for performance-related research. It was pointed out, however, that flexibility is the key and that international LTPP participants are not obligated to adopt identical procedures or quantities.

International Conference on SHRP and Traffic Safety on Two Continents

The International Conference on SHRP and Traffic Safety on Two Continents, held in Gothenburg, Sweden in September 1991 was jointly planned by VTI in Sweden and TRB. The program had parallel sessions with SHRP LTPP the focus of one session and traffic safety the topic of the other.

I-IMS User Group Meeting

An I-IMS User Group meeting was held in connection with the International Conference on SHRP and Traffic Safety on Two Continents. Representatives from Australia, Austria, Canada, The Netherlands, Finland (for the Nordic countries), the United Kingdom, and the United States were present. The structure of the I-IMS was discussed, as was the plan to send I-IMS data to the United States to be incorporated in the NIMS.

Also discussed were coordination of international users with SHRP, activities transitioning LTPP from SHRP to FHWA, the status of IMS development, IMS data releases, and the quality assurance and quality control of data. As the development of the I-IMS and cooperation among countries continues, other I-IMS User Group meetings will be held.

The workshops in Gothenburg in 1987 and Bath in 1988 formed the basis for the SHRP workshops held in England in 1990 and in Sweden in 1991. The workshops gave the international community an opportunity to discuss the research and consider the plans for implementation of LTPP research results obtained by SHRP and the participating countries. The questions raised by the international community and the answers produced as a consequence helped define the worldwide LTPP program. This program will benefit the international highway community in its future research to optimize construction and maintenance procedures.

The effort to unite the road-related research activities of the international community has succeeded as more than 10 countries are now conducting LTPP studies. Still other countries are joining the program and planning to implement the monitoring of test sections. More than thirty countries have appointed international coordinators and are receiving literature, information, and technical reports from SHRP.

I-IMS and the NIMS

Establishing the link between the NIMS and the I-IMS is an important component of the development of the NIMS. The international participants in the LTPP program show an increasing interest in adding data from their test sites into the NIMS and acquiring the data from the NIMS. This link will enable the researchers, worldwide, to access a universal database.

Data flow

Data from international LTPP participants will be stored in Washington in a database separate from the NIMS. The structure of the NIMS will not be altered and data from United States and Canada will continue to be entered in U.S. Customary units. Researchers who request data will receive American/Canadian data in U.S. Customary units and international data in SI or metric units. In the future, plans will be made to convert all data residing in the NIMS to SI units, and to enter, store, and report additional data in SI units.

Types of Modifications

The modifications to the NIMS necessary to make it a universal database include changes to the units of measure, measurement devices, and test methods.

Each of these changes requires other changes to the database. Modifications to some tables are required to change units. In order to modify the IMS to suit the individual country it is important to go through the Data Collection Guide and the Data Dictionary to identify the

tables where the units conversions are necessary. In some cases, new tables are necessary for different measurement devices or test methods. In other cases, codes may simply be added to codes tables to indicate a unique test method. New tables must be created and added to the I-IMS by the individual country.

Individual Reports

The following chapters present the reports from fourteen countries that have participated in long-term pavement performance research in cooperation with SHRP: Australia, Austria, Canada, Denmark, Finland, France, India, Japan, The Netherlands, Norway, Poland, Slovenia, Sweden, Switzerland, and the United Kingdom.

Australia

AUSTROADS, through the Australian Pavements Research Group (APRG), recognized the importance of SHRP and the potential for significant benefits to Australia. APRG and the State Road and Transport Authorities (SRTA) have sponsored a program of participation that maximizes Australia's exposure to SHRP research. In particular, an Australian SHRP Liaison Committee (LC) has been established. The primary role of the LC is to manage information transfer from SHRP and thus maximize the benefits to Australia (APRG, 1991a and b).

Long-Term Pavement Performance

LTPP is investigating a large number of pavement types in a diverse range of physical, environmental, and traffic conditions. The scope of the program makes it an excellent basis for improvement of Australia's structural pavement design methods and overall pavement performance and management theorems.

Under the auspices of APRG, the Australian Road Research Board (ARRB) is conducting a project called SHRP-LTPP Sections, through which suitable Australian pavement test sections are included in SHRP's LTPP effort. There are many advantages to participation.

- It will provide a direct link between the pavement performance in Australia and pavement performance in the United States and other participating countries. Australia's road researchers then will be able investigate the pavement load and performance relationship data.

- It will give Australia direct access to the data collected as it becomes available.

- Australia will be much more involved in the data analysis and interpretation of results.

- It will give Australia an internationally known data base management system for the storage, handling, and analysis of pavement research data.

- It will offer Australia a standard set of field and laboratory testing procedures and subsequently a standard data collection system.

- It will offer Australia evaluations of pavement condition measurement equipment and analysis procedures.

Australian SHRP-LTPP Sections

The recruitment of Australian pavement test sections for LTPP began in July 1991. SRTA were invited by ARRB to participate in the project by including pavement test sections.

Very early in the recruitment process, it became difficult to organize SPS test sections due to resource requirements such as money, people, and overall financially implied requirements. Responses from SRTA stated that existing pavements for the GPS were more acceptable.

SRTA were invited to select pavement test sections from the experimental definitions for the GPS (see Appendix 4).

ARRB implemented a recruitment network comprising selection, verification, and approval stages to facilitate the inclusion of Australian pavement test sections into the LTPP international program (Figure 1). The recruitment network structure was modified from the structure used by SHRP (SHRP, 1988). Individual SRTA select candidate projects (such as pavement test sections). These are submitted to ARRB for verification. During the verification stage, ARRB liaises with the SRTA to determine whether the candidate project is appropriate and how well it meets the SHRP selection criteria. The verified candidate projects are then submitted by ARRB to SHRP for review and inclusion in the LTPP international program.

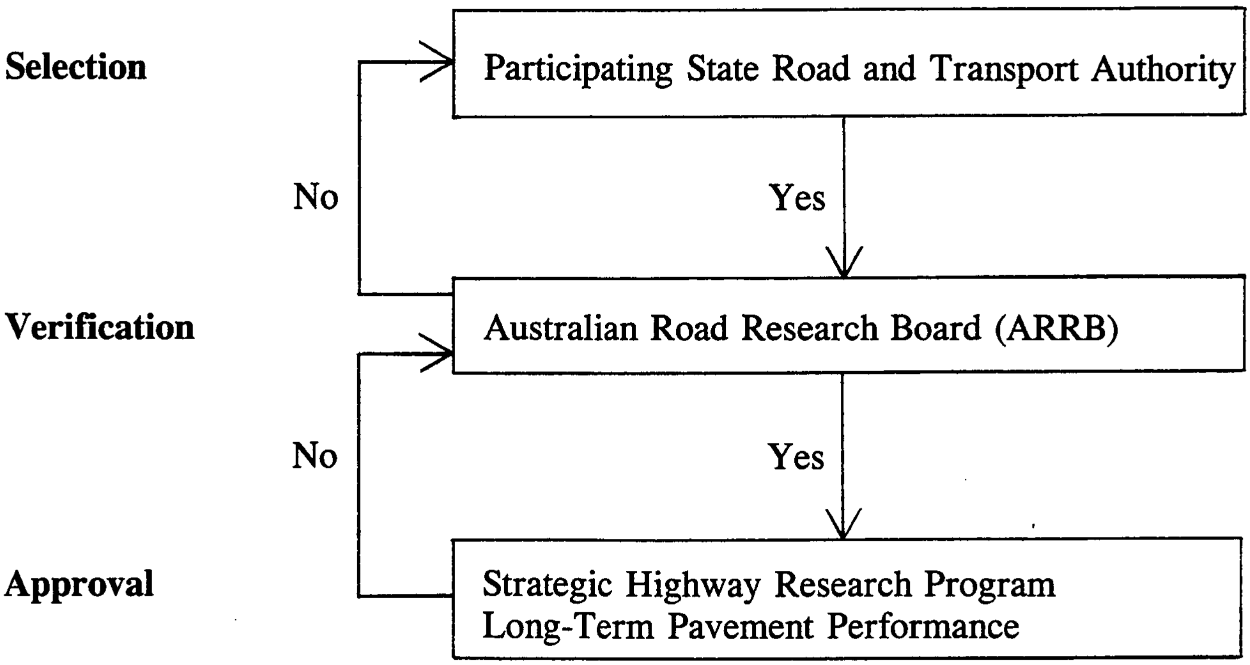

Figure 1. Australian SHRP-LTPP project recruitment network flowchart

As a result of ARRB's invitation to SRTA, nine pavement test sections have been approved by SHRP for inclusion into the LTPP international program (Table 1).

Table 1. Australian SHRP-LTPP international pavement test sections.

Pavement Test Section Number	GPS Experiment Number	Location	Year Opened to Traffic	Recruitment Status
NS03	GPS-3	Federal Highway (NSW)	1981	Approved
NS17	GPS-5	Foreshore Road (NSW)	1979	Approved
QL02	GPS-1	Bruce Highway (QLD)	1985	Approved
QL04	GPS-2	Warrego Highway (QLD)	1981	Approved
VC01	GPS-2	Western Ring Road (VIC)	1992	Approved
VC02	GPS-2	Western Ring Road (VIC)	1992	Approved
VC03	GPS-2	Western Ring Road (VIC)	1993	Approved
VC04	GPS-2	Western Ring Road (VIC)	1993	Approved
VC05	GPS-2	Western Ring Road (VIC)	1993	Approved

NSW: New South Wales; QLD: Queensland; VIC: Victoria

Data Collection and Management

The data recommended by SHRP for collection from the approved pavement test sections are considered in two broad categories. The first is basic inventory data, which includes items that remain constant over the monitor period unless the pavement is resurfaced or rehabilitated. The second is monitoring data, which includes items that will change with time and will require periodic measurements or updating during the monitoring period.

The data to be collected under the LTPP program are: inventory; material tests; traffic; distress; profile; deflection; skid resistance; environment; maintenance; and rehabilitation. The data will be collected by the participating SRTA with assistance from ARRB as required for certain data types. It was realized from the outset that the type and frequency of data collection as recommended by SHRP was beyond the scope of Australian participation. Each SRTA is tailoring the data collection within its capabilities, noting the requirements set by SHRP.

The collection of the data will require a storage and management facility. SHRP realized this from the outset and developed an Information Management System (IMS). ARRB has a copy of the International Information Management System (I-IMS), has installed the software, and will use the system to store the Australian pavement test section data as it becomes available. The data also will be transferred to the I-IMS at the Transportation Research Board in Washington, DC. The I-IMS also will allow non-Australian data to be transferred to it for analysis purposes.

Conclusion

The ongoing collection of data will lead to both detailed analysis in Australia and guarantee the availability of SHRP-LTPP outputs. It also will provide a calibration between Australian conditions and the performance relationships which will be the major output of the U.S. study.

The future analysis of data also will provide a strong backbone for improvement of Australia's structural pavement design methods, as well as performance and management models.

Austria

Site selection

In 1990 the Austrian Ministry of Economic Affairs entrusted the Road Research Division of the BVFA Arsenal (Federal Institute for Testing and Research) with the performance of tests which should provide benefits both for the Austrian road authorities and SHRP-LTPP. For this purpose six road sections with a length of 2 to 6 km (1.2 to 3.7 miles) were selected from roads that were determined for overlay to be carried out in 1991. After deflection measurements with the Lacroix deflectograph, we chose six sites, each with homogeneous bearing capacity (Figure 1).

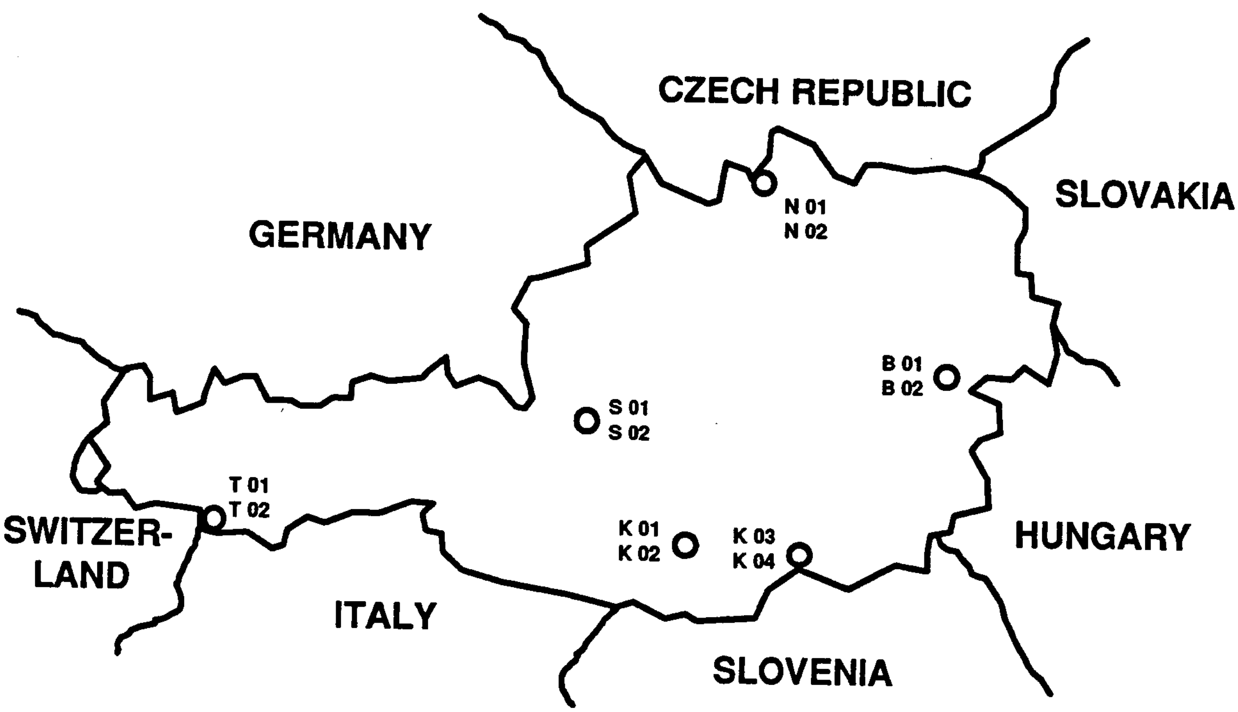

Figure 1. Location of test sites in Austria.

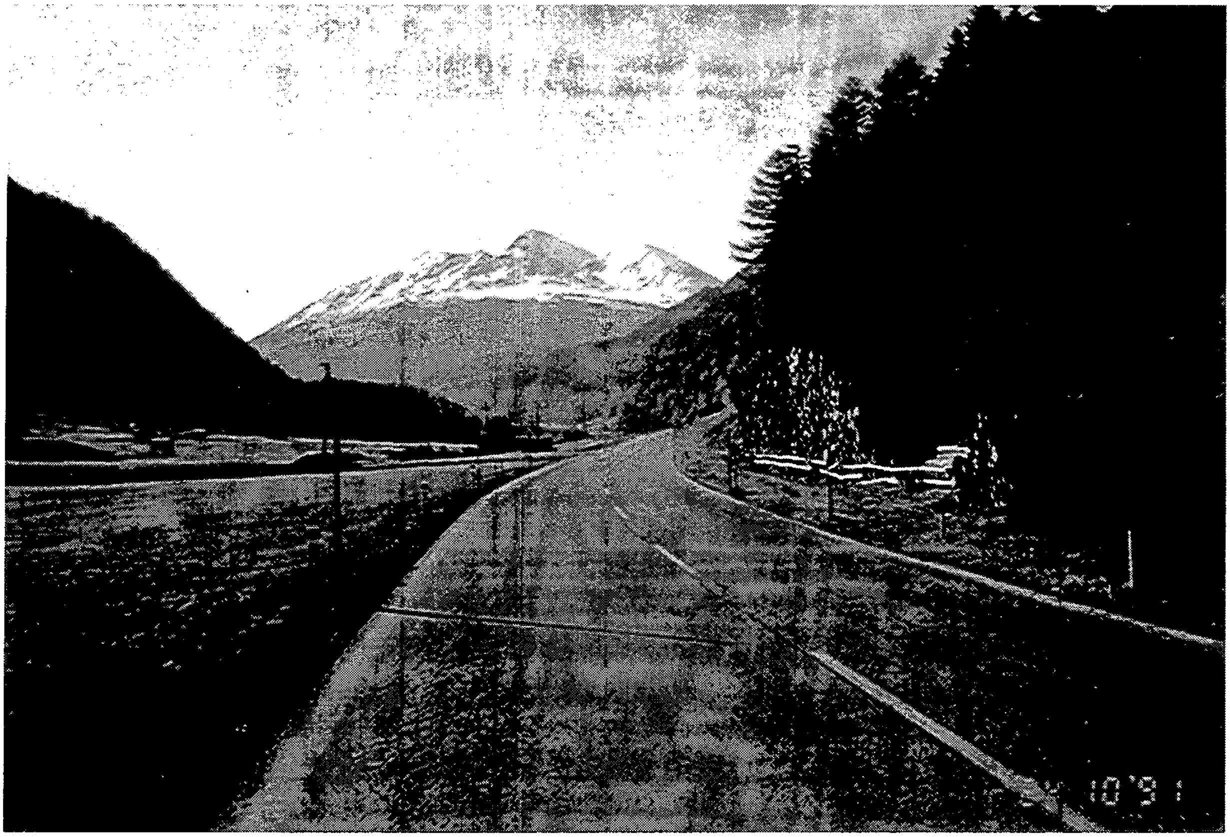

Figure 2. Test section T 01 before overlay.

These sites differ as far as climatic and traffic conditions are concerned. As the whole of Austria lies within the wet and freeze zone, the climatic differences are only due to the altitudes of the sites, which range from 300 m (984 ft.) above sea level in the province of Carinthia (K 01—K 04) to 1700 m (5,577 ft.) in Tyrol (T 01, T 02) (Figure 2).

All Austrian test sites are asphalt overlay on old asphalt pavements (GPS-6B). Each test site consists of two adjacent test sections with rather short transition zones. The difference between the two sections lies in the thickness of the overlays. At test site 6 T, for instance, the overlay thicknesses are 10 cm and 5 cm (3.93 and 1.92 in.), respectively (Figure 3).

Figure 4 shows the twelve test sections of Austria in terms of SHRP cells with the letters designing the province in which the test section is located.

Measurements and investigations

At all test sections measurements and investigations were made on the original construction and then the asphalt overlay was placed. Next, the first series of measurements after overlay were carried out. All site investigations are conducted following the SHRP procedures as much as possible. We use the following methods:

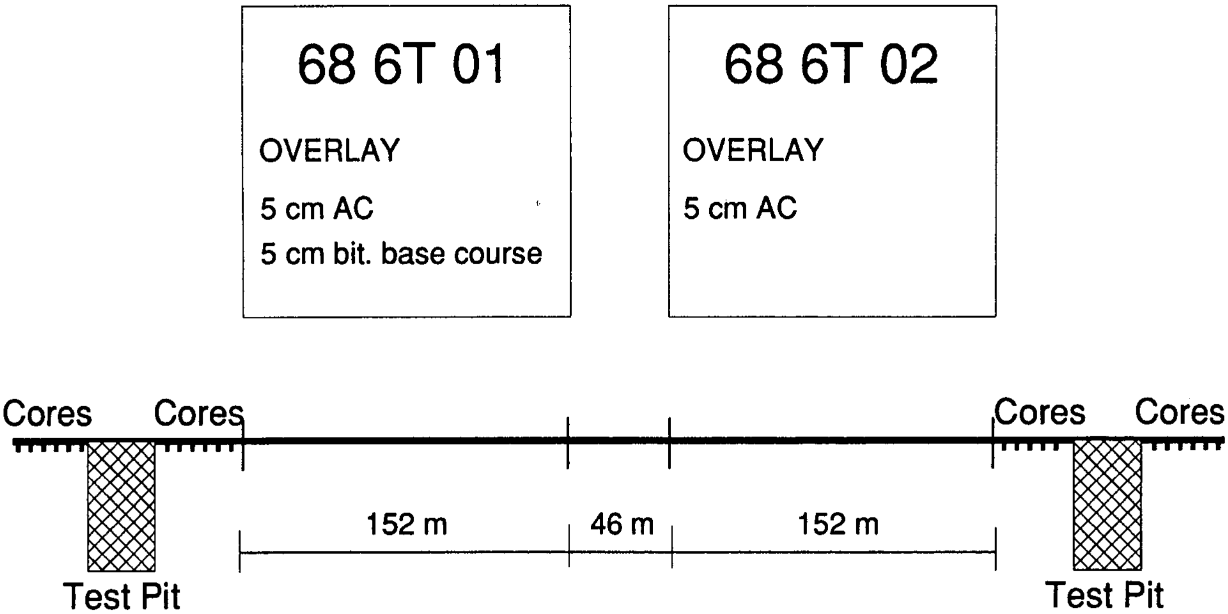

Figure 3. Longitudinal section of a test site

OVERLAY THICKNESS	ORIG. PVT. STRUCT. NR.	ORIG. PVT. COND. LEVEL	MOISTURE: WET; TEMPERATURE: FREEZE; SUBGRADE TYPE: F; TRAFFIC RATE: L	F; H	C; L	C; H
L	L	B		K2	K4	T2
		G			N1	
	H	B				
		G				
H	L	B		K1	K3	T1
		G			N2	
	H	B		B1 B2		
		G		S1 S2		

K Carinthia
N Lower Austria
B Burgenland
S Salzburg
T Tyrol

Figure 4. Selected test section

- Test pits, two at each site (see figure 3):
- Sampling of material (asphalt cores, unbound material);
- Plate loading test at each level of the unbound layers (base, subbase, subgrade) in the test pit;
- Density measurement at each level of the unbound layers;
- Longitudinal profile measured with rod and level in both wheelpaths at an interval of 0.3 m (1 ft.) and a resolution of 0.025 cm (0.01 in.). To fix the longitudinal profile exactly for all following measurements, every 30 m (98 ft.) of a test section a copper plate was nailed to the old surface which we deflected with eddy current methods.
- Cross profile measured with the planum (cross profilometer, which draws a diagram of the cross profile) at intervals of 15 m (49 ft). The height of either end of the transverse profile was measured with a levelling instrument in order to assess the crossfall and the theoretical water-depth, respectively (figure 5).

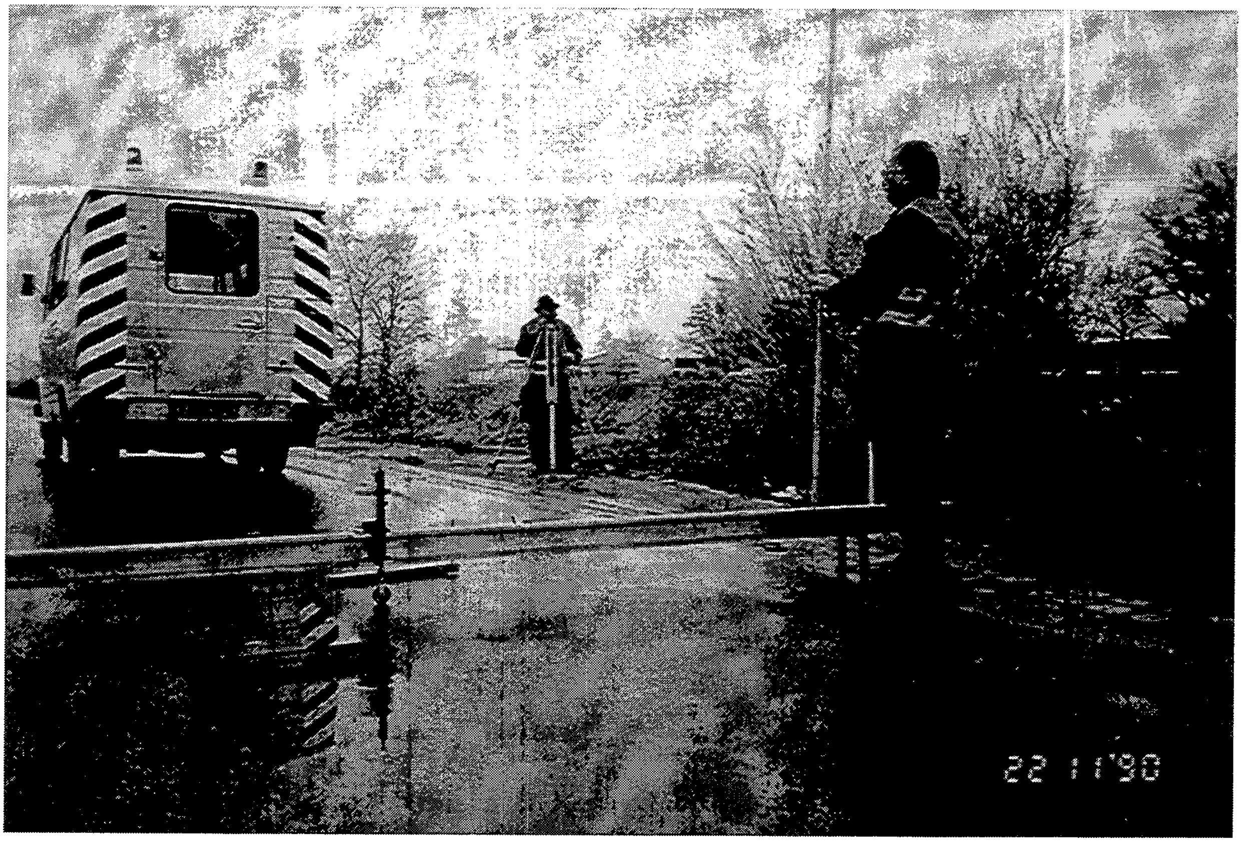

Figure 5. Measurement of the cross profile with "Planum"

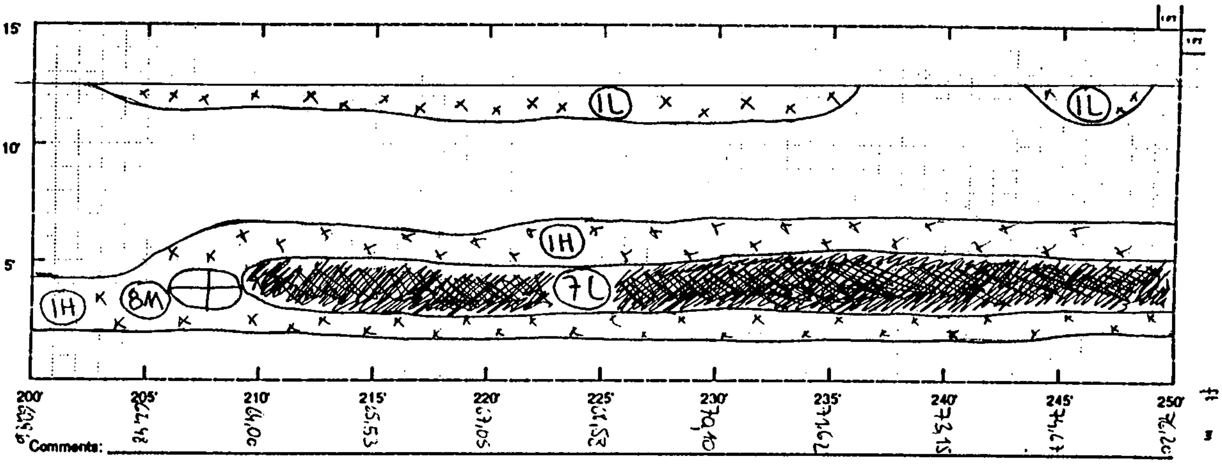

Figure 6. Hand-drawn distress map

- Condition of the existing pavement (surface distress) documented by
  1. photography, with a photo taken every 5 m (16 ft.) from a height of 3 m (10 ft.) and
  2. hand-drawn distress maps made according to the *Distress Identification Manual for the Long-Term Pavement Performance Project* (SHRP, 1993) (figure 6).

- Falling-weight deflectometer measurements according to SHRP procedures (Manual for FWD-Testing, Operation Field Guidelines) with the Dynatest FWD model 8000 series. Where possible, we got two falling-weight deflectometer measurements before overlay: one in spring and one just before the new asphalt was laid. Now, after application of the overlay we will measure twice a year: once in spring and once in summer or fall.

- Thickness measurements: The analysis of pavement performance requires exact data describing the thickness of the overlay. Therefore aluminum foils were spread on the existing road before the application of the asphalt layer, which allowed exact measurements of the thickness with the so-called Permascope equipment.

- Skid resistance has been measured (with locked wheel, at 60 km/h (37 mph) using a PIARC Standard tire) with the "Stuttgarter Reibungsmesser" equipment (Figure 5).

Traffic Data Collection

Four of the six sites are equipped with weigh-in-motion equipment. We have installed the Golden River system at these sites.[1] The two remaining sites soon will be equipped with a PAT system for weigh-in-motion. This system was provided by the Federal Ministry for systematic traffic and axle load analysis in the Austrian road net. The installation of the weigh-in-motion sensors, the inductive loops and the Golden River traffic data collectors at all sites was carried out by a contractor (Figure 7).

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[1]For information on the Golden River weigh-in-motion systems, see SHRP, 1991, p. 81.

Figure 7. Installation of the weigh-in-motion sensor.

Figure 8. Traffic data collector at the Lavamünd site (K3, K4)

Figure 8 shows the weigh sensor, the inductive loops and the box containing the traffic data collector.

Material tests

The material tests were performed in accordance with the procedures described in the "SHRP-LTPP Guide for Field Materials Sampling, Testing and Handling" (SHRP, 1990). In general, the same material tests are carried out in the United States as in Europe. Yet, there is one exception: the Resilient Modulus for unbound materials and for asphalt concrete, which we considered so important that we decided to learn how to handle it. And we do hope to come to an agreement with FHWA on the exchange of test specimens or artificial specimens followed by a comparison of data. As soon as we have acquired the skills to perform these tests we will start testing the material samples from the SHRP-LTPP test sections in Austria.

The Information Management System has been installed on our computer and is being tested now.

Canada

The Canadian Strategic Highway Research Program (C-SHRP) is a cooperative effort funded by the ten provincial, two territorial and the federal governments of Canada through their respective departments of transportation. The parallel goals of the program are to extract the benefit of the U.S. Strategic Highway Research Program (SHRP) effort and to extend SHRP research to areas of particular interest to Canada. C-SHRP is active in each of the four technical research areas of SHRP.

Within the Long-Term Pavement Performance (LTPP) studies, C-SHRP members have contributed test sections to both the General Pavement Studies (GPS) and Specific Pavement Studies (SPS) experiments of SHRP LTPP. These sections are integral to and form a portion of the U.S. studies. In addition, C-SHRP has three complementary research projects in LTPP which seek to extend the study concepts to areas of particular Canadian interest. One of these projects is the Canadian Long-Term Pavement Performance (C-LTPP) project, which is the subject of this report.

Goal of the Study

The goal of the C-LTPP project is to increase pavement life through the determination of cost-effective rehabilitation methods. The project builds upon the Canadian sections in the U.S. LTPP studies to include additional sections of typical pavements found in Canada.

The project objectives are to evaluate Canadian practice in rehabilitation of flexible pavements, to enhance the applicability of SHRP pavement prediction models to Canada and to establish common, national methodologies for pavement research. The project therefore has objectives both independent of and dependent on the U.S. LTPP.

Project Organization

C-LTPP is closely modelled upon the United States' studies. One substantial difference is in the operation of the project. Test sites have been established in all ten provinces, with the individual provinces responsible for nearly all aspects of data gathering, testing and reporting. The role of the C-SHRP staff is limited to coordination and management of the individual activities, and some contracting of special activities (Table 1).

Each province has appointed a C-LTPP contact engineer (often the same as the SHRP contact engineer) responsible for ensuring the various site activities are carried out in accordance

with the *Pavement Research Technical Guidelines for Canadian Long-Term Pavement Performance* (C-SHRP, 1989). Coordination of the activity across Canada is the responsibility of the C-LTPP Engineer on staff with C-SHRP in Ottawa. The contact engineers and the C-SHRP staff meet annually to ensure compliance, to share experiences and to improve the operational aspects of the project.

Table 1. Project Activities and Responsibilities

One-Time Activities	Responsibility	Ongoing or Annual Activities	Responsibility
Test site identification	Agencies	Traffic monitoring	Agencies
Signing and marking	Agencies	Annual condition:	
Materials sampling	Agencies	▸Profile	Agencies/C-SHRP
Prior conditions:		▸Distress	Agencies
▸Distress	Agencies	▸Strength	Agencies
▸Profile	Agencies/C-SHRP	▸Friction	Agencies
▸Strength	Agencies/C-SHRP	▸Environmental data	C-SHRP
Materials testing	Agencies/C-SHRP	Maintenance monitoring	Agencies
Site rehabilitation	Agencies	Data management	C-SHRP
Evaluation of spring factor	Agencies	Analysis	C-SHRP
Historical data collection	Agencies	Reporting	C-SHRP
		Project management	C-SHRP

Project Recruitment and Approval

Test section recruitment was undertaken on a targeted, by-request basis to satisfy the requirements of the sampling matrix (figure 1). Test sections were requested on a provincial basis (there are no federal or territorial sections in C-LTPP) to reflect common regional practice, to which non-typical rehabilitation sections were then added.

Sampling Framework

The sampling framework is a blend between the present GPS-6B and SPS-5 experiments of SHRP (figures 2 and 3). The C-LTPP experiment considers to-be-rehabilitated flexible pavements on granular bases. The sampling template extends the SHRP freeze/no-freeze climatic categories to include high freeze and low freeze conditions. With a few exceptions in coastal regions, all of Canada experiences seasonal freezing periods. The second extension of SHRP sampling criteria in canada is the addition of lower traffic levels than in the U.S. studies. The "low traffic" level in SHRP represents high traffic in many regions of Canada, so traffic has been divided at 30,000 ESAL per lane, per year in order to better reflect Canadian traffic levels, and to include more appropriate climate and traffic interaction

ENVIRONMENT	WET			DRY
FREEZING INDEX	LOW		HIGH	HIGH
SUBGRADE / TRAFFIC	FINE	COARSE	FINE	FINE
LOW	**1** Ontario Quebec Nova Scotia PrinceEdward Island New Brunswick British Columbia (3 OL/2 OP)	**2** Ontario Quebec Nova Scotia Newfoundland New Brunswick British Columbia Prince Edward Island (3 OL/1 OP)	**3** Ontario Quebec (2 OL)	**4** Alberta Saskatchewan Manitoba Northwest Territories Yukon (3 OL/2 OP)
HIGH	**5** Ontario Quebec Nova Scotia New Brunswick British Columbia (3 OL/2 OP)	**6** Ontario Quebec Nova Scotia New Brunswick British Columbia Newfoundland (3 OL/1 OP)	**7** Ontario Quebec (2 OL)	**8** Alberta Manitoba Saskatchewan (3 OL/2 OP)
	10 sites	8 sites	2 sites	10 sites
				30 sites

Legend:

Ontario / Quebec / Nova Scotia / New Brunswick / British Columbia — **5** — (3 OL/2 OP)

5 ← **cell identification number**

Ontario ... British Columbia ← **those jurisdictions having pavements under these cell conditions**

(3 OL/2 OP) ← **minimum test sites required**

*** 3 OL = three overlay sites having two test sections each**

***2 OP = two other paired test sites having recycled/milled sections**

Figure 1. Canadian long-term pavement performance test site sampling matrix.

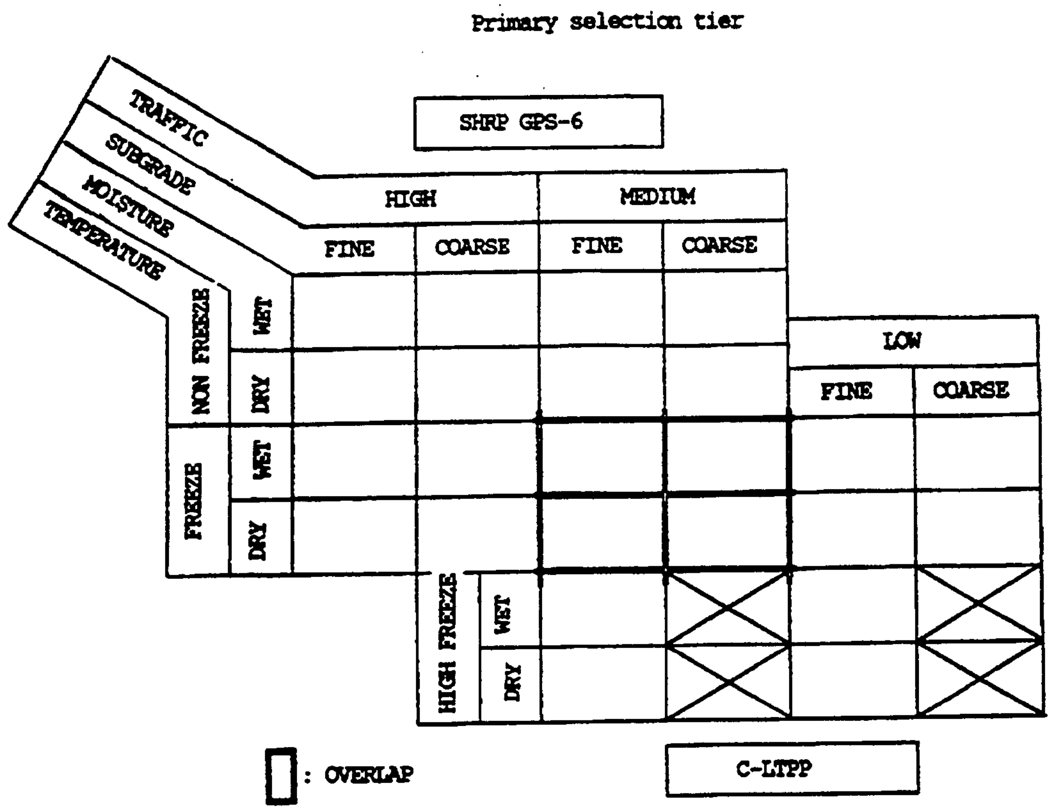


Figure 2. Link between SHRP GPS-6 and Canadian LTPP.

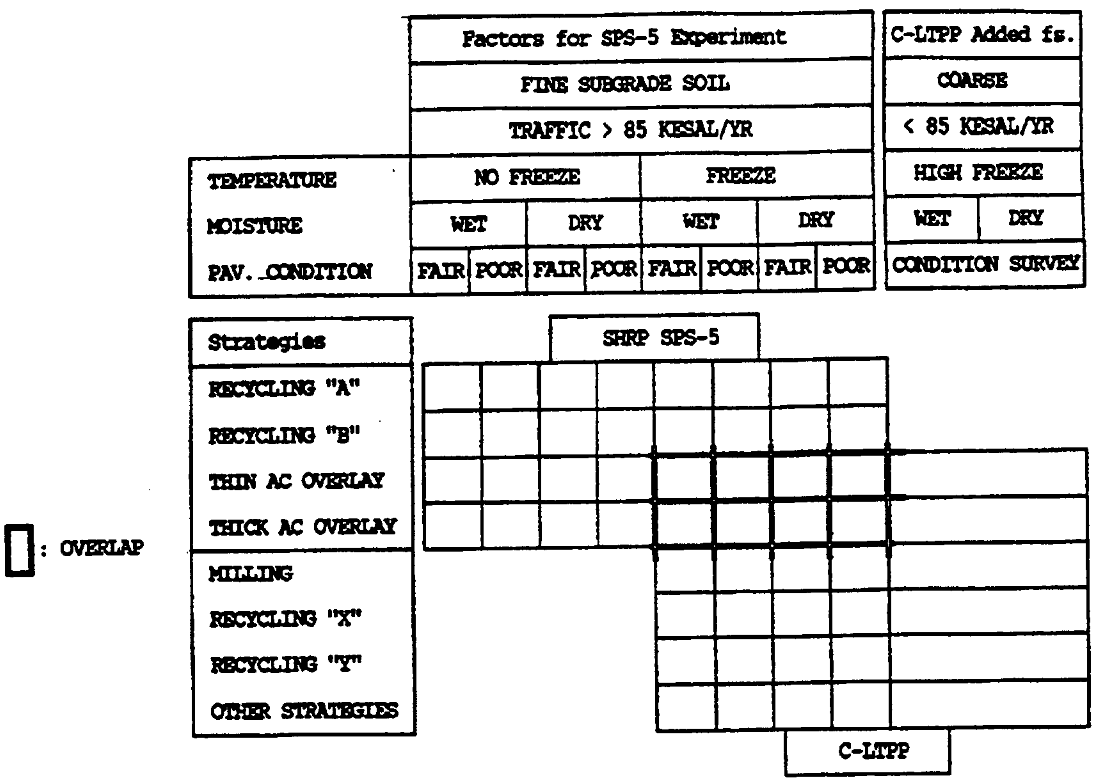


Figure 3. Link between SPS-5 and Canadian LTPP.

conditions. The third unique feature of C-LTPP was the requirement for the sites to be rehabilitated within the study so that prior condition of the pavement could be assessed. This factor was subsequently added to the GPS-6 study with the creation of GPS-6B.

Each test site was established at a location where rehabilitation was planned within an agency program. Test sites consist of a minimum of two sections, where one section is the planned agency rehabilitation and the second is a variation from the planned rehabilitation. Agencies were then encouraged to add additional sections comprising other rehabilitation methods. In most cases, the basic experiment consists of the planned agency overlay at each site and a variation in thickness of the overlay (usually either one-half or twice the thickness of the agency design). Other variations in rehabilitation method include milling, recycling and mix variations (such as premium asphalt binders). The resulting experiment comprises 23 test sites with 65 test sections.

The experiment was not designed as a rigorous statistical study, but rather intended to complement and extend the SHRP studies to include more typically Canadian pavement conditions. At the same time, the multi-section design at each test site provides a direct comparison of local rehabilitation practice with other compatible approaches.

Data Collection Program

In order to meet the objective of establishing common methods for pavement research data collection, C-LTPP was organized such that individual provincial highway agencies are responsible for essentially all data collection activity. Only those speciality activities or those requiring equipment not widely available have been designated for C-SHRP to perform. Technical guidelines have been prepared which outline the sampling and testing protocols used by the individual agencies. These guidelines closely follow those of SHRP but have been modified to bridge between the state of the art methods used by SHRP to the state of the practice techniques used by highway agencies in Canada. In addition, some individual tests have been excluded and others added, again to better reflect Canadian practice and interests. The remainder of this section discusses the data collection activities by noting differences in the LTPP and C-LTPP methods, rather than reviewing each activity in detail.

Field Material Sampling

All drilling, sampling and materials testing has been performed by the individual highway agencies. The sampling and testing scheme follows that of SHRP with few exceptions (figure 4). Most sampling, including test pits, was performed prior to rehabilitation of the pavement. A second series of sampling and testing on the new layers undertaken thereafter. California Bearing Ratio (CBR) testing has been undertaken both in the field (at the test pit) for all unbound layers (no bound bases in C-LTPP) and companion laboratory CBR have also been performed. Additional efforts to characterize material frost susceptibility and the availability of moisture also were undertaken. Resilient modulus testing (yet to be completed) is advancing on a selective rather than an all-inclusive basis. Only asphaltic layers and subgrade materials will be tested, with values for granular layers to be selected based upon the database of SHRP values for base and subbase courses.

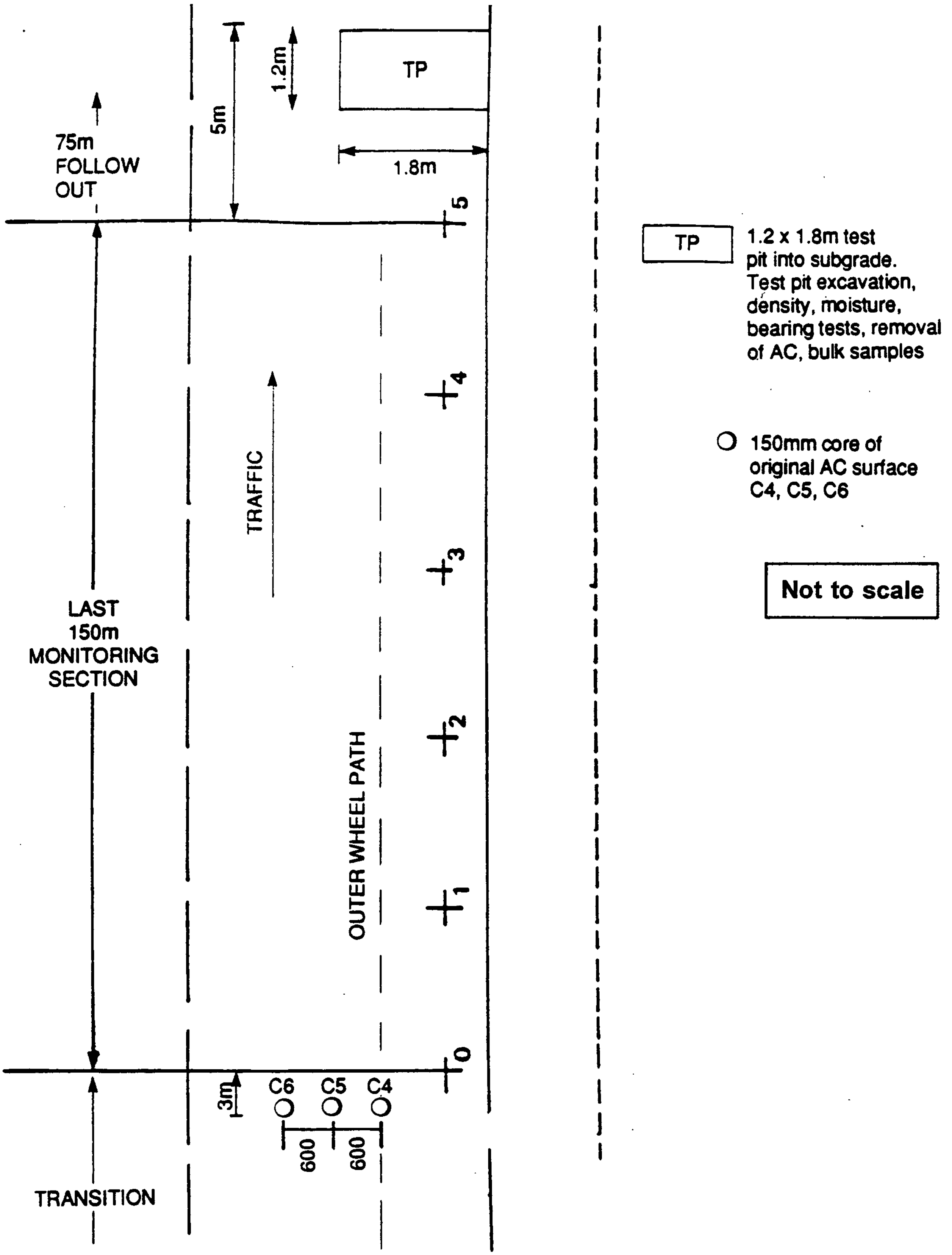


Figure 4. Sample locations for the last test section.

The additional C-LTPP testing (CBR) has also been undertaken by provinces at test sites contributed to the SHRP GPS experiment. Other differences between C-LTPP and similar LTPP guidelines are minor, and relate to using some Canadian designated test methods which are directly analogous to the U.S. counterparts.

Distress

Distress surveys are undertaken manually based upon the surface condition guide included in the C-LTPP Technical Guidelines Manual. This condition rating system is similar in nature to the SHRP guide, but includes additional separation of distresses and five levels of severity for each distress type rather than three provided by SHRP. The C-LTPP distresses are compatible for combining or collapsing data into the SHRP categorization.

Manual mapping of each 30-m (100-ft) subsection is carried out according to the distress guide. The rater classifies type and severity of distress and draws the extent onto the grid map for each subsection (figure 5). A separate table is available on the form for noting general distresses affecting the entire subsection, such as ravelling. The distress maps are supplemented by a series of sixteen 35-mm color photographs taken every 10 m (33 ft.) along the section. The photographs are used to compare rating of sections performed by different individuals.

Data reduction is accomplished manually by simply entering each distress event by subsection, from beginning to end. The event record consists of the type and severity (already coded in the field) and a grid count of either length or area depending upon the distress type. The distress map spreadsheet then calculates actual lengths and areas by applying the lane width scaler to the grid counts (while subsection length is fixed, lane width can vary from site to site). General distresses affecting the entire subsection are entered last. Locations of distresses are stored only by subsection and order of occurrence within the subsection. Comparison of distress locations before and after rehabilitation for instance, must be performed manually. For data analysis purposes, macros are written to combine the individual distresses into index measurements.

Distress surveys have been undertaken at each test site prior to rehabilitation, after rehabilitation and annually in the same month of rehabilitation since. Additional surveys have been taken on any sections receiving treatment in advance of the overlay being applied (such as milling and patching) to identify the effect of the treatment on the surface, prior to the overlay. Similarly, distress surveys are required immediately in advance of any surface maintenance activity and a companion survey indicating the distress treated in each instance.

Deflection

C-LTPP utilizes a combination of a falling-weight deflectometer (FWD) and Benkleman beam (BB) testing to characterize site material properties and section deflections over a cycle of performance.

Form SD1

C-LTPP Surface Defects Mapping Form

Localized Defects Mapping

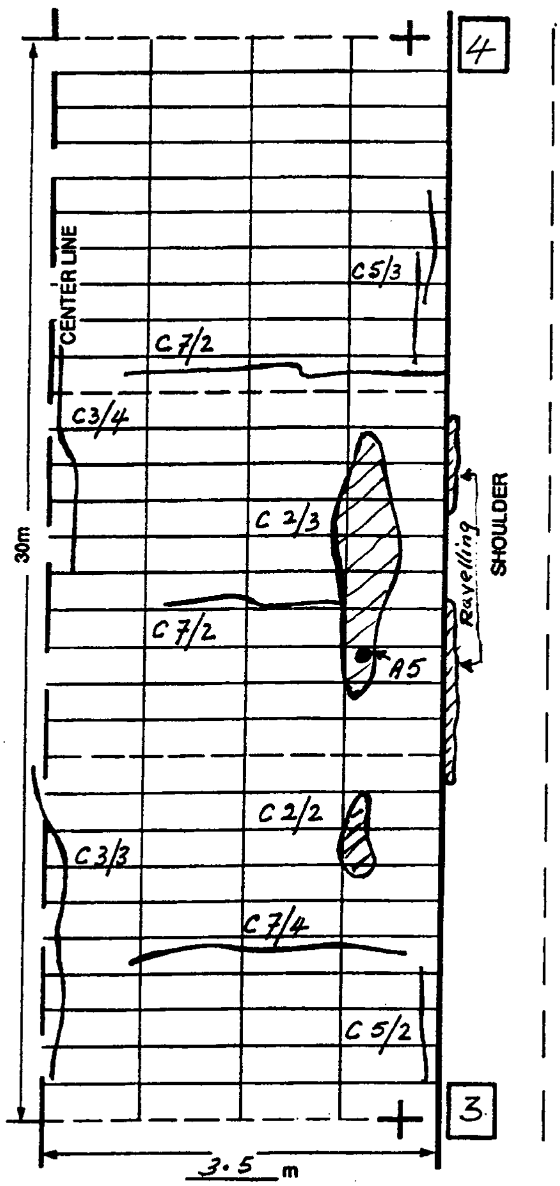
Host Jurisdiction ______________________

C-SHRP I.D. Number __ __ __ __ __ __ __

Road # or Description ______________________

Site Location ______________________

Survey Date: ______________________



Example of Surface Defects Mapping

UNIFORM DEFECTS

Type	Severity	Extent
Ravelling (A2)	Slight	80%
Polishing of Agg(A4)	Moderate	75%

REMARKS

Ravelling shoulders 30-50mm dropoff

Average alligator cracking block ≈ 150 mm

Figure 5. Manual mapping form.

The BB is used as the mainstay deflection instrument to gauge the effects of spring thaw, seasonal variation, yearly variation and the effect of the rehabilitation. The FWD is used more sparingly to track the changes with age. BB testing is undertaken by the provincial highway agencies in accordance with the BB protocol include with the C-LTPP technical guidelines. FWD testing is done under contract to C-SHRP according to the SHRP FWD protocol. In each case, sixteen test points are required in each test section for one sequence.

Using the BB, each section has been tested to measure the influence of the rehabilitation on the deflection of the section. A series of tests was performed prior to the rehabilitation and immediately after, and a ratio of before to after deflection calculated for each section. In addition, FWD testing was undertaken in the fall of rehabilitation for reach section. Subsequent FWD testing has been performed each second fall after rehabilitation.

More intensive monitoring is undertaken with the BB. Each agency is responsible for measuring the spring, seasonal and annual variation in deflection with the BB. Spring deflection is tracked by weekly BB testing of each section leading up to maximum spring deflection. As maximum deflection approaches, in the opinion of the host agency, testing is increased to daily until measurement indicates the peak has passed and strength is recovering. Weekly testing than resumes until the spring testing cycle reaches eight weeks in total. For expediency, agencies might use a deflection device other than BB for the lead-in and trail-out periods, but must use the BB (and the companion device) when measuring the peak. Measurement of the spring factor cycle must be undertaken in two of the first five years of site monitoring.

Seasonal variation is also measured using the BB and consists of monthly testing during the non-freeze months. Again, this sequence is to be completed twice during the first five years of C-LTPP.

Annual testing is performed using the BB in the month during which rehabilitation occurred. In addition, companion BB testing is performed when FWD work occurs.

The aim of the deflection testing program is to build typical deflection cycle plots for each section by combining and extrapolating the spring, seasonal and annual measurements. A separate project (Pavement Response Studies) extends the seasonal and spring testing by incorporating instrumentation (moisture, temperature, deflection, strain) and more intensive monitoring at a subset of four C-LTPP test sites.

The first series of FWD tests was performed in 1989 before SHRP established a protocol for reference calibration of FWD load cells. The work was done under contract by Dynatest Canada. The device used was reference-calibrated subsequent to the work done for C-LTPP. In 1991, FWD work was performed for C-LTPP by the Ministère des Transports du Québec under a cooperative agreement with C-SHRP. The device used was a nine-sensor unit manufactured by Dynatest with its first service being the C-LTPP work. Reference calibration was performed at the Cornell University calibration facility. During the C-LTPP testing cycle comparative work was done with the Dynatest FWDs owned by Alberta Transportation & Utilities.

Reduction of FWD data has not been initiated, awaiting further decisions on data analysis and modelling prior to proceeding.

Profile

The C-LTPP technical guidelines require the determination of relative elevations along each wheel path, in a closed survey loop and six cross-sections. The principle method of measurement is with the Dipstick manual profile device. Some agencies have resorted to rod and level surveys because of operational difficulties with the software for this device. In either instance, the guideline requirements are for the longitudinal profile to be on a 300-mm (12-in.) footprint and the cross-sections at 50 mm (2 in.).

Results are reported digitally on diskette and a summary sheet with turning point elevations accompanies each submission. The surveys are required to close within normal limits. The closure is used as the quality control measure. To date, data entry and verification have been completed, but no data reduction or manipulation has been performed.

Skid

While skid resistance is often a factor triggering maintenance or rehabilitation, it is not a parameter that is regularly measured in most regions of Canada. As a result its inclusion in C-LTPP monitoring is encouraged, but not a required monitoring element. The agencies that monitor skid for C-LTPP most commonly use the ASTM E294 locked wheel skid trailer. Transport Canada (formerly the Canadian Good Roads Association) owns a test device and collects data for those agencies requesting it, primarily in eastern Canada.

Traffic

The C-LTPP traffic requirement closely parallels SHRP's, except that only summary data is reported by the provincial agencies, with no requirement to retain and transfer raw traffic records. In most instances, provinces have developed traffic data collection plans to accommodate both their C-LTPP and SHRP GPS/SPS sites, resulting in much of the same equipment type and methods being utilized for both programs.

Three data sheets contain the summary traffic data required by C-LTPP. The first requires design traffic data consisting of AADT, percent trucks, total trucks, ESAL truck factor, total ESAL, design life, and design ESAL in the C-LTPP lane for both the original pavement and for the rehabilitation. In addition, agencies have reported similar volume and distribution data for the C-LTPP lane since the time of original construction, using whatever means are available for such determination. In each instance the agency describes the process from which the data is derived. After rehabilitation, agencies report truck volume for each week classified by the FHWA 13 bin classification as determined by either a full-time AVC or by a full-time WIM. Data are submitted annually in the weekly tables. Although some sites were constructed as early as 1989, the guidelines only requires that the minimum AVC be in full-time operation by June 1991.

In addition to the requirement for AVC data, the minimum data requirements call for seven-day continuous weighing of trucks for each truck season, to be gathered in consecutive seasons at least once prior to June 1993.

In most instances, traffic monitoring has begun only in 1991 leaving data submissions sparse to date. Good success has generally been encountered in estimating or retrieving historical traffic data prior to rehabilitation.

Future Monitoring Plan

C-SHRP member agencies have committed to monitor site performance for at least fifteen years. The monitoring will continue to be the responsibility of the individual provincial agencies, under the overall direction of the C-LTPP staff engineer and the present and future data analysis contractors. A major deliverable of the five-year data analysis effort to be completed in March 1994 is expected to be a commentary on the data collection process. The commentary is anticipate to affect the type, quality, and quantity of data collected in future years, based upon modelling choices and sensitivity analyses anticipated.

The transition of the responsibility for FWD testing from C-SHRP to the individual member agencies has also been targeted for 1994. This would leave C-SHRP the management, coordination, and analysis roles only. Under the current program philosophy, even the analysis role should eventually become the responsibility of the individual agencies.

Information Management System

Originally, C-SHRP planned to adopt the SHRP-IMS for data management purposes, and obtained hardware and software for the system. However, the numerous releases of the IMS during its development required too much staff and led to a decision to delay implementation of the system until development was nearly final. In the meantime, the backlog of data, much of it in paper form became awkward. To resolve this problem, all C-LTPP data has been entered into a spreadsheet program that interfaces with the program used for the IMS. This provisional step has allowed data entry to proceed without implementation of the SHRP IMS. Having the data in spreadsheet form allows for easier verification, checking and preliminary analysis. Eventual conversion to an I-IMS is anticipated using Oracle Datalens 1-2-3, but has not been scheduled.

Data Analysis

Within the complementary research element of C-SHRP, analysis of LTPP (all LTPP studies) was targeted early as an area for complementary effort. Since 1990 C-SHRP, under C-LTPP, has invested considerable resources in exploring and developing alternative analytical tools. In particular, prototype Bayesian statistical software for use in developing pavement performance prediction models has been developed. These Bayesian methods are a more generalized form of regression analysis which allow monitoring data from LTPP to be combined with historical knowledge, in a rigorous mathematical environment. The historical

knowledge may take the form of old data bases, existing models or subjective judgement. Two of the many benefits of Bayesian analysis are that it overcomes the small sample problem typically encountered in pavement modelling (and even in LTPP) by bringing previous knowledge to the analysis, and it promotes in the LTPP environment an evolution from the current state of knowledge to the new state which will be unveiled incrementally as LTPP data continues to be collected in to the future.

Numerous background reports, pilot analysis and training materiel in these methods have been developed by C-SHRP.

France

France has had test section programs with very specific aims for about twenty years. The concerns of managers also can be addressed through participation in the SHRP LTPP international program. The French contribution is characterized by pavements especially adapted to very heavy traffic (axle loads of 13 metric tons) and constituted by either hydraulic binders, stabilized materials, or bituminous materials in full thickness. In situ evaluation began in 1992 on approximately 22 test sections.

Objectives of Study

The objectives of the French study are to have the advantage of a homogeneous research frame in an international field, and to analyze the effects of heavy traffic on structure and maintenance.

Project Recruitment and Approval

The sections are located on the national road network and on the network managed by the toll motorways companies. The study is financed by the roads ministry and the toll motorway companies.

Experimental Design and Sampling Frame

The test sections were chosen from new or maintained flexible pavements.

Environmental Factors

The sections are located in metropolitan areas. The climate in these areas is similar to the United States' North Atlantic region, although the winters are not as severe.

Pilot Study Testing

The tests are performed by the Laboratory for Bridges and Roads (Laboratoires des Ponts et Chaussées). The activity is coordinated by the Central Laboratory for Bridges and Roads (LCPC).

Data Collection Program

The measurements generally follow SHRP's specifications. The adjustments to accommodate local conditions are noted below.

Conduct of Field Material Sampling

In view of the great thickness of the stabilized materials used in the pavements, only tests on core samples will be performed. The properties of the bearing soils are obtained from construction records.

Materials testing

Methodology If there is a test specified by SHRP and by France, the French standard will be used. For some tests not standardized in France (such as AC resilient modulus), equipment has been purchased to perform the test according to SHRP specifications.

Distress

Equipment Surveys of the surface will be performed every three years with the System of Investigation of Roads by Analysis of Numerical and Optical data (SIRANO), a multifunction apparatus, with 35-mm photographic film.

Data Collection The SHRP method will be used.

Deflection

Equipment A Dynatest 8000 falling-weight deflectometer will be used.

Data Collection SHRP's method will be used.

Data Reduction SHRP's method will be used.

Equipment Calibration The calibration will be limited to the one planned by Dynatest. There is no calibration rig for the falling-weight deflectometer.

Profile

Equipment The survey by using a longitudinal profile analyzer on the SIRANO multifunction apparatus at 72 km/h (45 mph).

Data Collection The profile data are recorded every 25 cm (10 in.).

Data Reduction France will use the International Roughness Index (IRI).

Equipment Calibration The longitudinal profile analyzers (APL) are calibrated periodically by a calibration rig.

Skid

Equipment The skid resistance will be measured by the Sideways Force Coefficient Routine Investigation Machine (SCRIM). The pavements' macroroughness will be measured with the Rugolaser on the SIRANO apparatus.

Data Reduction The method to be used is the sideways force coefficient (SFC) and texture depth by sand patch test.

Traffic

Equipment Traffic characteristics will be measured by means of piezoelectric cables.

Data Collection The data collected will be broken down according to traffic volume and distribution, and by typical axle loads by vehicle class.

Traffic Data Processing and Analysis Vehicle classification will be used.

Equipment calibration Each weighing station will be calibrated before use.

General Monitoring Plan for the Future

The 22 test sections will be monitored according to SHRP procedures for at least five years. The monitoring plan will be modified if the traffic rate changes.

Information Management System

The data from the sites will be entered into the French Information Management System according to SHRP's design.

India

Total transportation cost is fast emerging as a versatile tool for optimizing the allocation of resources for road development and repair. The objective of India's long-range Pavement Performance Study is to develop pavement deterioration models and data for total transportation cost models for Indian conditions. This project is a sequel to the already-completed *Road User Cost Study in India* on road user cost models (Central Road Research Institute 1982).

Objective of Study

The objective of the Pavement Performance Study is to develop data for total transportation cost models for Indian conditions, which may be achieved by:

- development of pavement performance data for materials normally used in India;
- based on the performance data, development of layer equivalencies, as feasible;
- limited studies on effect of maintenance level on the pavement performance;
- generation of data on construction and maintenance inputs of different pavements.

Project Recruitment and Approval

The project is sponsored by the Ministry of Surface Transport of the Government of India. It is being implemented by the Central Road Research Institute (CRRI).

Study Management

Management at CRRI The Central Road Research Institute is implementing the project. A core group is performing the tasks of planning, scheduling, monitoring, analysis, reporting, and the field and laboratory work. Also, staff from other expert divisions of the institute are involved in the laboratory and field work for the evaluation of pavement materials, quality control, periodic performance observations, and data processing.

Committees and Expert Working Groups Technical committees have been formed to guide and monitor the activities of the study.

Steering Committee The Steering Committee decides policy matters and provides national-level guidance and monitoring of the project. The Steering Committee normally meets at six-month intervals.

Expert Working Groups Four Expert Working Groups (EWGs) review the study plans and documents, and provide expert guidance in the following areas of specialization:

- planning, data management, and analysis;
- investigations, performance monitoring, quality control, and cost productivity;
- instrumentation and special study; and
- material characterization studies.

The EWGs meet about twice a year. The recommendations of the EWGs are placed before the Steering Committee for necessary final decisions.

Association of State Research Institutes To obtain wider participation in the study, some of the state research institutes have been involved in the project for the associated field work under different climatic conditions.

State Public Works Departments The state public works departments (PWDs) are involved in the Existing Pavement Sections and the New Pavement Sections studies. For the Existing Pavement Sections, the PWDs make necessary arrangements for field work, provide information on past history of test sections, implement the maintenance measures suggested by the Institute, and provide feedback.

For the New Pavement Sections, the PWDs are to make the necessary arrangements for field work, perform preliminary identification of sites, identify borrow areas, carry out departmental construction and quality control as per requirements of the study, obtain data on construction costs of various specifications, implement maintenance measures, and provide feedback.

Experimental Design and Sampling Frame

Existing Pavement Sections

The scope of the study on existing pavement sections has undergone modifications at different times. The revised study parameters included in the plans are given in table 1.

A section matrix with 20 cells and 60 sections, as given in table 2, was planned in the initial stages. In view of the various field problems, the sections as envisaged for each cell were not available. There were originally a total of 73 test sections, each of 0.5 km length, which were subsequently increased to 113 and monitored as given in table 3, to cover the various study parameters.

Table 1. Study on Existing Pavement Sections revised study parameters

Pavement state	Original Construction	Premix Carpet surface (PC*)
		Semi-Dense Bituminous Concrete (SBDC)
		Asphaltic Concrete Surface (AC)
	Overlaid	PC/SDBC/AC
Traffic	Medium	0.4-0.8 mesa/lane/year (600-1200 commercial vehicles/day)
	High	More than 1.0 mesa/lane/year (1500 commercial vehicles/day)
Climate	Dry/Semi-Arid	Rainfall <500 mm/year
	Moist/Sub-Humid	Rainfall >500 mm/year
Condition	Good	No defects
	Fair/Poor	>10 percent area defects
Age	Young	<5 years
	Old	>5 years
Maintenance	Normal level	
	Higher than normal level	
	Nil/Deferred level	

*PC is a 20-mm thin open graded wearing surface with binder content of 14.6 kg/10 m^2 and stone chippings 0.27 m^3/ 10 m^2 (13.2 mm size, passing 22.4 mm sieve and retained on 11.2 mm sieve and 11.2 mm size, passing 13.2 mm sieve and retained on 5.6 mm sieve, in 1:2 proportion). Data as of February 1989.

Table 2. Minimum planned number of sections required in revised matrix

	Pavement Condition			
	Dry Climate		Moist Climate	
Pavement State	Good	Fair/Poor	Good	Fair/Poor
Original	2	2	4	4
Overlaid	--	--	--	--
Premixed carpet surfacing				
Young	2	2	4	4
Old	2	2	4	4
Asphalt concrete surfacing				
Young	2	2	4	4
Old	2	2	4	4

Table 3. Distribution of test sections in the modified design matrix

Pavement Condition:		Medium to High Traffic				Total
		Dry Climate		Moist Climate		
		Good	Fair/Poor	Good	Fair/Poor	
Original Construction*		6 (-6)†	4 (-1)† 5§	6	10	31 (-7)†
Overlaid less than 5 years	PC	10 (-2)†	6 (-2)† 1§	5 (-3)†	3 (-2)† 6§	31 (-9)†
	AC	2 (-2)†	--	5 2§	3 (-4)† 2§	14 (-6)†
	SDC	2§	2§	8§	8§	20
Overlaid more than 5 years	PC	2	1 (-1)†	3 (-3)†	2 (-2)† 1 (-1)†	8 (-6)†
	AC	1	2 (-2)†	1	2§	7 (-3)†
	SDC	--	2§	--	--	2
Total		23 (-10)†	23 (-6)†	30 (-6)†	37 (-9)†	113** (-31)†

May 1990
* PC: Premix carpet with seal; AC: Asphalt concrete; SDBC: Semi-dense bituminous concrete
† Sections resurfaced by PWD but observations continue
§ Additional sections
** This number does not include 6 sections of mix seal surfacing that are also being observed.

New Pavement Sections

The New Pavement Sections study will generate data on road costs and refine the pavement deterioration models developed from the Existing Pavement Sections. The study consists of one main study and three sub-studies to account for different subgrade types, climatic, and traffic conditions. The study parameters are given in table 4.

The subgrades are broadly classified into three categories viz clayey, alluvial and gravelly. Their strength taken for experiment design would depend upon the location where sections are to be laid and the soil characteristics available there. Each section is 100 m long with 10 m transitions between the sections. The experiment design for one of the sub-studies on clay subgrades is given in table 5. The sites for other sub-studies have been preliminarily identified and investigations for finalization are in progress.

Environmental Factors

The test sections under EPS are spread over in four provinces, of different environmental conditions. The sections are grouped into two environmental zones:

Table 4. New Pavement Sections study parameters

Pavement Materials	
Subbase	Granular materials like moorum*/gravel, including mechanical stabilization with a minimum soaked CBR of 20
	Lime/cement-based stabilization
	water-bound macadam (WBM)-II
Base	Conventional WBM Wet mix macadam Bituminous macadam/dense bituminous macadam Crushed stone
Surfacing	Flexible pavements: Mix seal surfacing Premix carpet with seal Asphaltic concrete (bituminous concrete) Semi-dense bituminous concrete
Subgrade Type and Strength	
Clayey	CBR of the order of 3
Alluvial	CBR of the order of 4 to 7
Gravelly	CBR of the order of 10
Traffic	F-category (cvpd 1500-4500) E-category (cvpd 450-1500)
Maintenance Strategies	Normal level Higher than normal level Deferred
Thickness levels	5 to 6 levels covering overdesign to about 25 percent, and underdesign to about 50 percent for the main study; 2 to 4 levels in other areas

*a disintegrated rock material

Dry: <500 mm/yr (Rainfall); and
Moist: >500 mm/yr (Rainfall).

Under NPS, the sites are located in different regions of varying environmental, traffic and subgrade conditions.

Pilot Study Testing

It was not considered essential to undertake any pilot study testing in view of large experience and expertise gathered on different aspects of test track studies conducted at CRRI during the last four decades.

Table 5. Substudy S-II on Bangalore-Pune Road (NH-4) experiment design

Site #	Surface course	Base course*	Gravel subbase	Remarks
1	20 PC	+250 II/III	+200	Replicate
2	20 PC	+150 III	+200	Normal maintenance
3	20 PC	+250 II/III	+150	Normal maintenance
4	25 SDC + 50 BM	+150 II/III	+150	Normal maintenance
5	20 PC + 50 BM	+250 II/III	+150	For hard shoulders
6	20 PC + 50 BM	+250 II/III	+150	Replicate
7	20 PC	+250 II/III	+150	Normal maintenance
8	20 PC	+250 II/III	+200	Normal maintenance
9	25 SDC + 100 DBM	+150 III	+150	Normal maintenance
10	20 PC	+250 II/III	+300	Deferred maintenance
11	20 PC + 50 BM	+250 II/III	+150	Normal maintenance
12	20 PC + 75 BM	+250 II/III	+150	Normal maintenance
13	20 PC	+250 II/III	+300	Normal maintenance
14	20 PC	+150 III	+150	Normal maintenance
15	20 PC	+250 II/III	+150	Higher maintenance
16	25 SDC + 100 DBM	+150 III	+150	Replicate
17	40 AC + 75 DBM	+150 III	+150	Deferred
18	25 AC + 75 DBM	+250 III	+150	Normal maintenance
19	40 AC + 50 DBM	+250 III	+150	Normal maintenance
20	25 AC + 75 DBM	+250 III	+150	Deferred
21	25 AC + 50 DBM	+150 III	+150	Higher
22	40 AC + 75 DBM	+150 III	+150	Hard shoulder
23	40 AC + 75 DBM	+250 III	+150	Normal maintenance
24	25 AC + 50 DBM	+150 III	+150	Normal maintenance
25	40 AC + 75 DBM	+150 III	+150	Normal maintenance
26	40 AC + 75 DBM	+150 III	+150	Normal maintenance
27	40 AC + 50 DBM	+150 III	+150	Higher
28	40 AC + 50 DBM	+150 III	+200	Normal maintenance
29	40 AC + 50 DBM	+150 III	+150	Normal maintenance
30	25 AC + 100 DBM	+150 III	+150	Normal maintenance
31	25 AC + 75 DBM	+150 III	+150	Normal maintenance
32	40 AC + 50 DBM	+150 III	+150	Replicate

* Contains water-bound macadam DBM: Dense bituminous macadam
AC: Asphalt concrete PC: premixed carpet with seal coat
BM: Bituminous macadam SDC: Semi-dense bituminous concrete

Data Collection Program

Over 400 sections were initially identified based on the information collected from the field regarding surface condition, history of road construction, the thickness of layers and the type of constituent material in them, year of the last surface renewal, and traffic data. Of these, about 250 sections satisfying the criteria for selection were investigated in detail to meet the requirements of the experiment design matrix. The finalized section matrix, which originally consisted of 73 sections, was subsequently enlarged to 113 sections. Six periodic performance observations at intervals of six months to cover the pre-monsoon and post-monsoon periods were originally envisaged in the study plans. At a later stage, when four series of performance observations were over, the proposed total number of observations were increased to ten along with the enlargement of section matrix to 113, which covered ten series for the original 73 sections and six series each for the additional 40 sections.

The details of the data collection program for material investigations, performance observations and other related aspects are given in table 4.

Conduct of Field Material Testing

Test pits of size 1 × 1 m were dug diagonally opposite on both ends of the section and about 1 m from the outer edge under the wheel path. Sections on widened roads were avoided to the extent possible. Wherever unavoidable, the pit was dug half on the widened portion and half on the original pavement. The field observations taken for each test location towards finalization included:

- pavement surface condition in detail;
- pavement deflection with Benkelman Beam at the center of the test pit location.
- The pavement was dug layer by layer and the following observations were taken and samples were collected, as required, for laboratory characterization. Deformations, if any, in the lower layers were measured. Some tests/observations taken from pits are as follows:
    - ♦ Bituminous layer: Thickness of bituminous layers and level of compaction. Limited samples were analyzed in the laboratory for binder content and grading.
    - ♦ Granular bases: Thickness of layers, level of compaction, quality of aggregates used, quality and quantity of filler material.
    - ♦ Stabilized Soil and Granular Subbase: Thickness of layers, quality of material used and degree of compaction.
    - ♦ Subgrade: Field dry density, moisture content
    - ♦ Embankment: Field dry density and moisture content randomly

Samples of soil were collected from each pit (other materials were collected randomly) for laboratory characterizations.

Materials Testing

Materials testing under EPS has been done only for subgrade soils. Various tests, such as Atterbergs limits (LL, PL, PI), soil classification, mechanical sieve analysis, proctor test (MDD & OMC), and the CBR test have been conducted according to the standard. Limited procedures and extraction tests for bituminous mixes are also done to study the aggregate and binder properties. Evaluation of in situ material properties with a falling-weight deflectometer is in progress on some selected sections. The sample plans for studies on Existing Pavement Sections and New Pavement Sections are given in tables 1 and 2, respectively.

Distress

Since all existing pavement test sections are on flexible pavements, the types of distress are grouped into four categories:

1. Surface defects: fatty surface (excess asphalt cement), smooth surface, streaking, and hungry surface (insufficient asphalt cement)

2. Cracks: hairline cracks, alligator cracks, longitudinal cracks, edge cracks, transverse cracks, block cracks

3. Deformations: slippage, rutting, corrugations, shoving, shallow depressions, settlements, and upheaval

4. Disintegrations: stripping, loss of aggregate, ravelling, potholes, and edge breaking

Equipment Physical measurements are obtained manually with scale or tape by measuring sizes or area of various distress modes. A rut depth gauge was used to evaluate both wheel paths (0.9 m from the edge in case of two-lane single carriageway 7 m wide; and 0.6 m from edge in case of single-lane carriageway 3.75 m wide) every 50 m. Automated measurements are not taken.

Data collection Measurements of magnitude of various distress modes, as enclosed in rectangular shape, for each 50 m segment in a 500-m-long section are taken for each of the three parts of carriageway (left/central/right). A data sheet for collecting this raw information is given in table 6.

Data Reduction The data collected from the field is calculated for percent area distressed (of individual distress types) with respect to the total surface area of the section. This is expressed separately for each of the carriageway segments. The data sheet devised for reducing data for use in the analysis is given in table 7.

Table 6. Data collection sheet for pavement surface conditions.

Name of the Road:
Category of the Road:
Test Section: EPS-H R U G Km. ________ to Km. ________

Carriageway width (m):
Date of observation:
Weather condition:

Location	Left/ Right/ Central	Patch work Size (m)	Patch work Area (m^2)	Cracks Class &Type of cracks	Cracks Length/ size (m)	Cracks area (m^2)	Potholes Size (m)	Potholes Area (m^2)	Bleeding Size (m)	Bleeding Area (m^2)	Depression/ Settlement Size (m)	Depression/ Settlement Area (m^2)	Rut Depth Max. (cm)	Rut Depth Av. (cm)	Ravelling Size (m)	Ravelling Area (m^2)	Any other	Remarks (Pavement Drainage & Shoulder condition)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19

Note: The distress is measured in segments of 50 m length.

Recorded by:

Table 7. Sheet for data reduction of pavement surface conditions.

Name of the Road:
Category of the Road:
Test Section: EPS-H R U G Km. _______ to Km. _______

Carriageway width (m):
Date of observation:
Area of the Section

Location	Patch work Area (%)	Cracks: Class &Type of cracks	Cracks: Length/size m	Cracks: area(%) (m^2)	Potholes Area (%)	Bleeding Area (%)	Depression settlement Area (%)	Rut Depth Max. (cm)	Rut Depth Av. (cm)	Ravelling Area %	Any other	Total Distress (50m Segment) Area (%)	Remarks
Total :													

Note: (1) The distress is measured in segments of 50 m length.
(2) For the purpose of calculation of area in the case of single crack, width of the crack is taken as 0.3 m.

Recorded by:

Deflection

Equipment The deflection measurements are taken with the standard Benkelman Beam.

Data Collection The deflection measurements are taken by loading a truck as to create a rear axle load of 8170 kg. The tire pressure at the rear axle is maintained at 5.6 kg/cm^2. The observations are taken by WASHO method as per the procedure laid down by IRC:81-1981 (Indian Roads Congress, 1991). Twenty-one observations are taken at staggered locations at an interval of 50 m in a test section of 0.5 km length. Details are shown in the figure on the data sheet shown in table 8.

For thick bituminous pavements, the temperature is measured by using glycerol and standard thermometer (0 to 100°C range) in a hole 10 mm diameter and 45 mm deep.

Data Reduction The temperature and moisture corrections are applied as per IRC:81-1981 table 9 to the data collected from the field, as per standard procedure. Data is reduced to calculate the average deflection and standard deviation. The deflection of the section is expressed as characteristic rebound deflection (in mm).

Equipment Calibration The Benkelman Beam is calibrated to ensure that the beam and dial gauge are working correctly. The beam is placed on hard, level ground and levelled. Metallic blocks of varying thicknesses are placed below the probe and the dial gauge reading is recorded each time. The dial gauge on the beam records one-half of the metal block if the beam is in good order. The beam pivot is checked for free and smooth operation.

Profile

Equipment A TRRL-type towed Fifth-Wheel Bump Integrator is used.

Data Collection The towed bump integrator is run at a constant speed of 32 km/h. The observations are taken on the outer wheel paths in both directions. The wheel paths are taken at a distance of 0.9 m and 0.6 m from the edges in the case of two-lane and single-lane pavements, respectively. The observations are taken until three consistent readings are obtained. The readings of integrating and wheel counters are noted in the data sheet as given in table 10.

Data Reduction The average roughness (unevenness in mm/km) for both outer wheel paths is determined and the mean of both averages is expressed as roughness (longitudinal profile) of the section.

Equipment Calibration A standard bump integrator unit is used to calibrate various field units. The standard unit and field units are run simultaneously on pre-identified road sections having different ranges of roughness (1500-10000 mm/km) and a correlation equation is

Table 8. Deflection data collection sheet.

Name of the Road:
Category of the Road:
Test Section: EPS-H R U G Km. to Km.
Carriage width:

Weather condition:
Shade temperature:
Pavement temperature:
Date of observation:

Dial gauge reading Particulars		Test Point No. (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	Remarks
Initial	1												
	2												
	3												
	Av.												
Intermediate	1												
	2												
	3												
	Av.												
Final	1												
	2												
	3												
	Av.												
Total deflection (mm)													
Residual deflection (mm)													
Corrected Rebound deflection (mm)													
Condition of test point													

Note: THE TEST POINT NO. AND DISTANCE LOCATIONS
TO BE SHOWN ON THE SKETCH ON THE BACK

TESTED BY

Table 8 (continued)

Dial gauge reading Particulars		Test Point No. (12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	Remarks
Initial	1											
	2											
	3											
	Av.											
Intermediate	1											
	2											
	3											
	Av.											
Final	1											
	2											
	3											
	Av.											
Total deflection (mm)												
Residual deflection (mm)												
Corrected Rebound deflection (mm)												
Condition of test point												

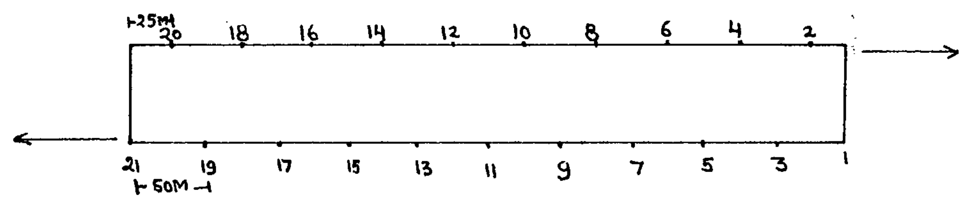


Table 9. Temperature and moisture corrections to the Benkelman Beam deflection.

Correction	Details
Temperature	Standard temperature: 35 °C
	Correction factor: 0.0065 × (difference of temperature)
	Negative if less than 35 °C Positive if more than 35 °C
Moisture	
During monsoon:	No correction
During dry months:	Clayey subgrade - 2 Sandy subgrade - 1.2 to 1.3
	Values are interpolated for intermediate soils

developed to calculate the calibrated roughness. The Abay beam has also been used for the calibration of response-type roughness devices.[1] Since the Abay beam was procured in the midst of the EPS study, the calibration of the towed bump integrator for this part of the study has been restricted to that with a standard unit only. Transverse profile (cross profile) is also measured with a 3-m straight edge. Transverse profile of the section is plotted each time.

Skid

Equipment The Mu-Meter (Mark-IV) is proposed to measure the sideways coefficient (skid resistance) on the NPS sites. Skid measurements are not performed on EPS sites.

Traffic and Axle Loads

Equipment For the study on existing pavement sections, the traffic census (traffic volume) has been done manually by recording the number of different class/types of vehicles in each direction. The axle load measurements have been done with portable wheel weighing platforms. For the location of main study on new pavement sections, it is proposed to use a piezoelectric weigh-in-motion system.

Data Collection Traffic surveys are conducted for 72 consecutive hours by field teams. There is a separate count point for each section, but if there are a number of continuous or nearby sections and there are no traffic diversions between, one count point is used for all such sections. All categories of traffic are included in the survey and data is recorded on the data sheet in table 11. The lateral placement of vehicles along the width of the road has also been recorded during the daytime to develop a correlation between distress development and

[1]Beam developed at TRRL, UK for calibration response-type roughness devices.

Table 10. Data sheet for roughness measurements.

Name of the Road:
Category of Road:
Test Section: EPS-H R U G Km._______to Km._______

Type of wearing course:
Surface condition (Visual):
Date of Testing:

Sr. No.	Wheel Path L / R	Direction	Number of Distance/Wheel Revolutions Counts	Bump Integrating Counter Reading (inches)	Unevenness Index (UI) value (mm/km)	Average U.I. (mm/km)
1.	L					
2.	L					
3.	L					
4.	R					
5.	R					
6.	R					

Tested By :

Table 11. Axle load survey data sheet.

Direction UP - 1
DN - 2

Road
State:
Section:
Direction of Traffic: Km. ------- to Km. -------

Name of Supervisor:
Location of Test point:
Date -------Time: From -----to -----

Vehicle Code	Commodity	RLW (T)	ULW (T)	Wheel Weight (T) Front	Rear	Rear	Rear	Wheel Weight (T) TDM1	TDM2	TDM3	TDM4	Tyre pressure Front	Rear (Kg/cm^2)	Remarks

Legend

RLW - Registered Laden Weight
ULW - Unladen Weight
TDM - Tandem

usage of pavement by the traffic. It is done by dividing the road width into 30 cm (1 ft.) segments and recording the position of the left-hand outer rear wheel across the width, as shown in figure 1.

The axle load survey is conducted for 72 consecutive hours, based on random sampling. It covers up to about 50 to 100 percent of the heavy commercial traffic on the roads depending upon the traffic intensity. Front and rear wheel weights are measured by stopping the vehicle and bringing on the weighing pads installed on the shoulders. Tire pressures are also measured for overloaded vehicles covering about 10 percent of the total vehicles weighed. The axle load measurements were originally planned twice a year, but subsequently changed to annual in view of the various field problems encountered. The data sheet for recording the measurements is shown in table 12. A typical equipment set up for load measurements in the field is shown in figure 2.

Traffic Data Processing and Analysis The daily traffic of various types of vehicles, direction-wise, is calculated by adding the vehicles of each category for 24 hours. The average of 72 hours' traffic (for vehicle class) is determined for each direction. The average daily traffic (ADT) for the test location is determined by adding the average of commercial vehicles in both directions. The ADT represents traffic on that particular section and is used to estimate the cumulative standard axles for analysis purposes.

Based on the axle load (twice the wheel load) data collected, the vehicle damage factor (VDF) and the equivalent standard axle loads (ESALs) are worked out by assigning equivalency factors to different axle groups based on AASHO findings.

Equipment Calibration The portable wheel weighers are calibrated by applying known loads under the test bed in the laboratory.

General Monitoring Plan for the Future

Some equipment has been procured recently for use in this study.

Falling Weight Deflectometer Factors such as the deflection profile, E-values of different pavement layers, and residual life are being evaluated on some of the selected test sections under existing pavement sections. The equipment will also be used for continuous monitoring of the nearby new pavement test sections.

Lacroix Deflectograph Present plans call for observation of the deflection profile of some of the EPS sites, and for continuous monitoring of nearby NPS sites.

Mu-Meter This device is proposed for skid resistance monitoring of the NPS sites.

Microprocessor-Based Bump Integrator This device will be used for monitoring roughness on NPS sites.

Figure 1. Ground markings for recording lateral placement of vehicles.

Figure 2. Axle load survey with portable weigh bridges.

Table 12. Data sheet for traffic volume count survey.

Name of the road:
Test Section: EPS-H/R/U/G Km.——— Km.———
Location: Km.______

Direction: Km. ______ to ______
Date ______ Day______ Time ______

Time (Hourly) / Vehicle Categoty	Bus	Two Axle Truck		Multi Axle Truck Semi-Trailor		Multi Axle Truck Truck-Trailor		Tempos, Pick-up Vans, Mini Bus		Tractor Trolly		Jeep Cars	Scooter/ M. Cycle	Tonga/ Bullock Cart/ Horse Cart	Cycle Cycle Rickshaw
		Empty	Loaded	Empty	Loaded	Empty	Loaded	Empty	Loaded	Empty	Loaded				

Recorded by:

Weigh-in-Motion System Traffic and axle load surveys on the main study site under NPS are to be performed using this equipment.

GDS Repetitive Triaxial Testing Equipment This equipment will be used to determine the material properties (soils subgrade only) under dynamic loading by simulating the field conditions in the laboratory. The equipment is supplied by M/S GDS Instruments Ltd., U.K.

MTS Repetitive Triaxial Testing Equipment The properties of granular material and bituminous mixes under dynamic loading conditions will be obtained with this equipment by simulating the field conditions in the laboratory. The equipment is supplied by M/S MTS System Corporation, U.S.A.

Information Management System

The guidelines as proposed by SHRP for long-term pavement performance data have not been followed for the EPS since this study was planned before LTPP, and involved standardization and formulating procedures similar to LTPP. Data collection for the NPS will follow the SHRP-LTPP IMS protocols as much as possible. The data could then be used in the SHRP-LTPP IMS to refine design procedures and pavement deterioration models throughout the world.

Japan

Various distress modes can be seen on in-service pavements in Japan, including permanent deformation, raveling, thermal cracking, fatigue cracking and potholes. These are caused by Japan's climate and by annually increasing heavy traffic loads. These conditions complicate both structure design and mixture design for asphalt pavement. Therefore no uniform equation or method for long-term performance has been developed in Japan.

The present *Manual for Design and Construction of Asphalt Pavement* is based on technical results from the AASHO Road Test, and has been updated several times to fit Japanese situations (Japan Road Association 1992). Requirements for pavement performance, however, have changed substantially. Japan must develop a new design method for asphalt pavement.

SHRP is a much bigger and more sophisticated road research program than the AASHO Road Test. The results from SHRP will establish a new theoretical design method for asphalt pavement in the United States. Because of the differences in design, construction, siting, performance, requirements, and other factors for pavements in the United States and Japan, SHRP's results might not be directly usable in Japan. In order to identify the differences, the Public Works Research Institute (PWRI) of the Ministry of Construction decided to participate in SHRP's LTPP program. The PWRI constructed LTPP testing sites in Japan and has conducted parallel research to that conducted in the United States. The organization of Japan's LTPP program is shown in figure 1. The international coordinator is the director general of the road department at PWRI. The pavement division of the road department is the executive office. Each testing site is under the control of the regional construction bureaus under the Ministry of Construction.

Japan has been participating in the GPS-2 (asphalt concrete with stabilized base) since 1988. This is the most common type of pavement used in national highways in Japan. The PWRI, in association with the regional construction bureaus, investigated the candidate sections for the GPS-2, and in 1990 selected twenty-eight newly constructed LTPP sites for the GPS-2 study.

Objective of Study

There could be differences between factors in the United States and Japan that influence pavement performance, such as soil conditions, materials, climates, and traffic loads. These differences must be clarified in order to apply the technical results from SHRP to pavement design in Japan.

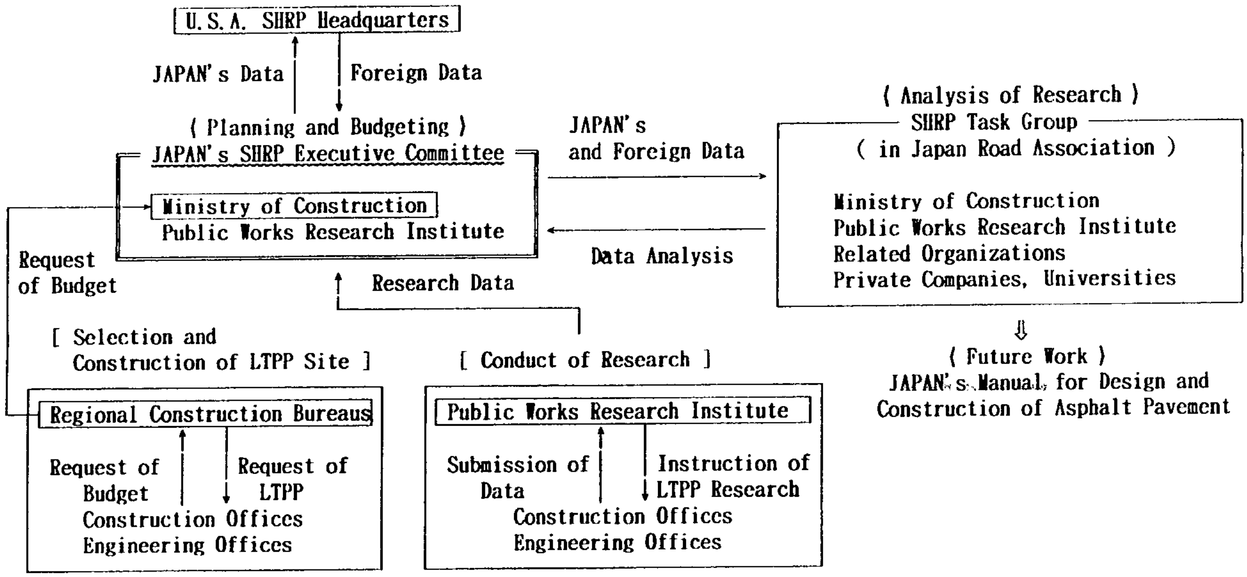


Figure 1. Organizational chart of Japan's LTPP program.

The primary purpose of Japan's LTPP program is to obtain data to modify the SHRP results to meet Japanese situations by comparing the Japanese and United States data. The specific objectives of this study are:

- to identify the factors that affect pavement performance in Japan and the significance of each factor.
- to establish a new theoretical design method based on pavement performance.

Project Recruitment and Approval

Japan initially planned to participate in several GPS projects. However, asphalt pavement is used to construct most national highways in Japan, so it was decided to participate in GPS-1 and GPS-2. Japan's LTPP testing sections are selected under the following criteria which meet the *Recruitment Guidelines for Additional GPS Candidate Projects* (SHRP 1988):

- Asphalt pavement
- Newly constructed or reconstructed pavement
- No steep grades and no small radius curves in horizontal alignment
- No transverse discontinuities such as culverts, pipes, and bridges
- No longitudinal underground structures within 1.2 m from pavement surface
- At least 300 m length without traffic signals, railroad crossings and bridges

These criteria are very difficult to meet in Japan. The PWRI in association with eight regional construction bureaus (Hokkaido Development Bureau) investigated possible sections on national highways managed by the Ministry of Construction. Most of the roads are exposed to very high traffic volume (greater than 3,000), so the pavement must have a strong

structure with a stabilized base.[1] As a consequence, the PWRI could not locate GPS-1 test sections. Twenty-eight newly constructed sections were located for the GPS-2 project (figure 2). Japan's LTPP test pavements and their characteristics are shown in table 1. In this table, all the test sections are assumed wet, because the PWRI has not yet obtained enough meteorological data. Traffic rates for all the sections are also assumed high in the future, although current rates for some sections are not so high (one-way daily traffic volume of heavy vehicles below 3,000). A pavement structure to be constructed at the selected test sections is shown in figure 3. Construction of the twenty-eight sections was finished in fiscal year 1990.

Experimental Design and Sampling Frame

A remarkable point on Japan's GPS-2 project is that all the test sections were newly constructed in order to better evaluate pavement performance.

Data collection activity is now under way in Japan, so detailed information on data classification is not available. If all the testing sections are "wet" with "high" traffic rate, sampling design and cell identification will be as shown in table 2. Most of Japan's test sections will be biased toward non-freeze, wet and high traffic volume conditions. However, these conditions are quite common in Japan, so the selected test sections represent Japanese highway situations very well.

Environmental Factors

Most of Japan has a temperate climate. Average rainfall is about 1700 mm/year, so it is very humid all over Japan. Pavement temperature exceeds 60°C in the summer and the heavy traffic volume is very high, so rutting is a predominant problem. In the northern part of the country, such as in the regions of Hokkaido and Tohoku, thermal cracking caused by low temperature and thermal cycling also are critical distress modes.

Pilot Study Testing

Japan has not performed any pilot study testing related to the LTPP study.

Data Collection Program

Much attention has been paid to each LTPP activity to follow the SHRP-LTPP guidelines (SHRP 1988, 1990b, 1990c). The *Recruitment Guidelines* and *Data Collection Guide* have

[1]Heavy vehicles include those that have a plate with one of the following numbers on it: 0 = construction machines among large-sized motor vehicles; 1 = cargo trucks; 2 = buses (passenger capacity of 11 or more); 8 = small or ordinary motor vehicles for special use; 9 = special large-sized motor vehicles (excluding construction machines and others). Load limit: 5 tons for wheel load, 10 tons for axle load and 20 tons for gross weight of a vehicle.

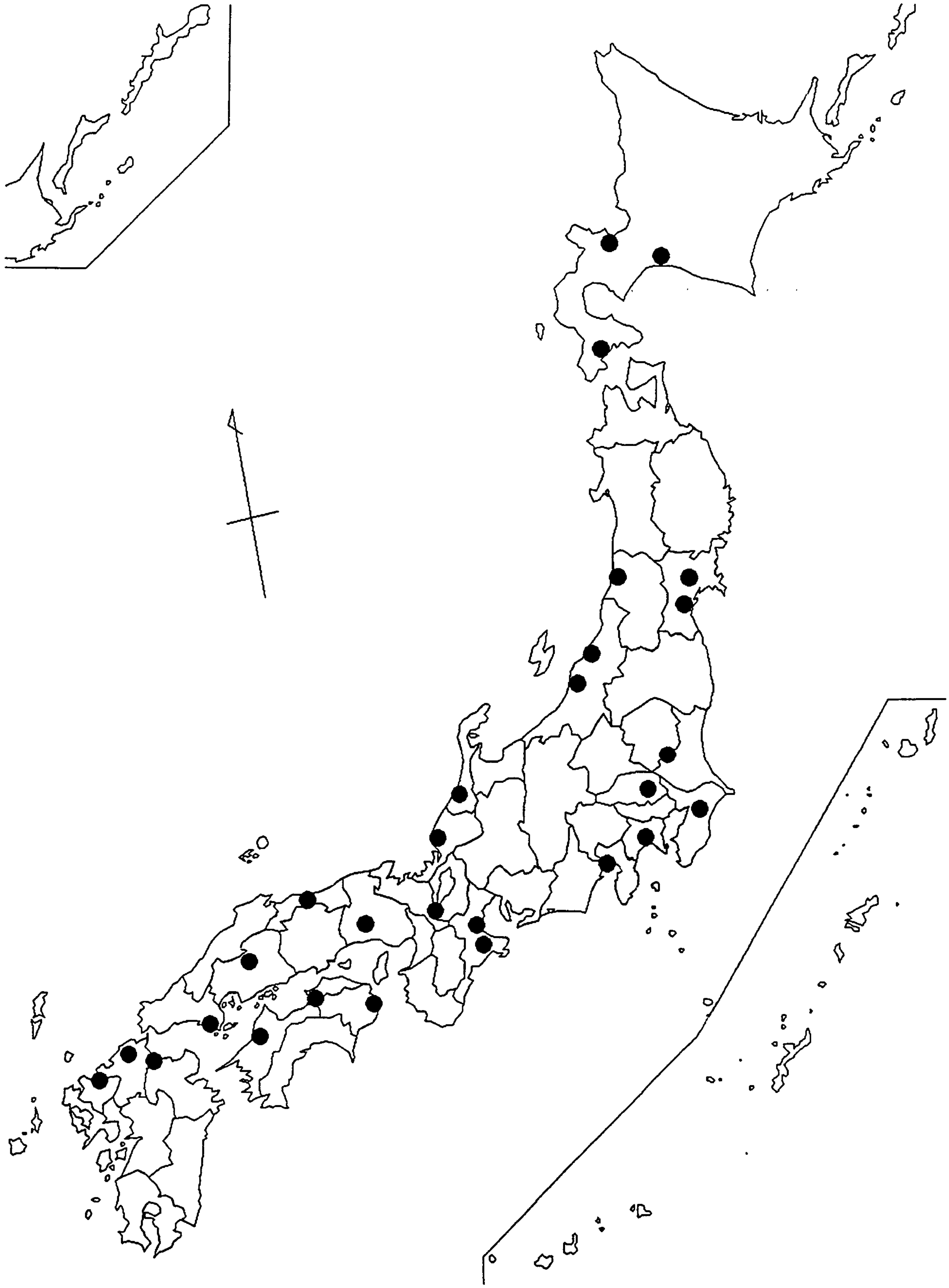


Figure 2. GPS test sections in Japan

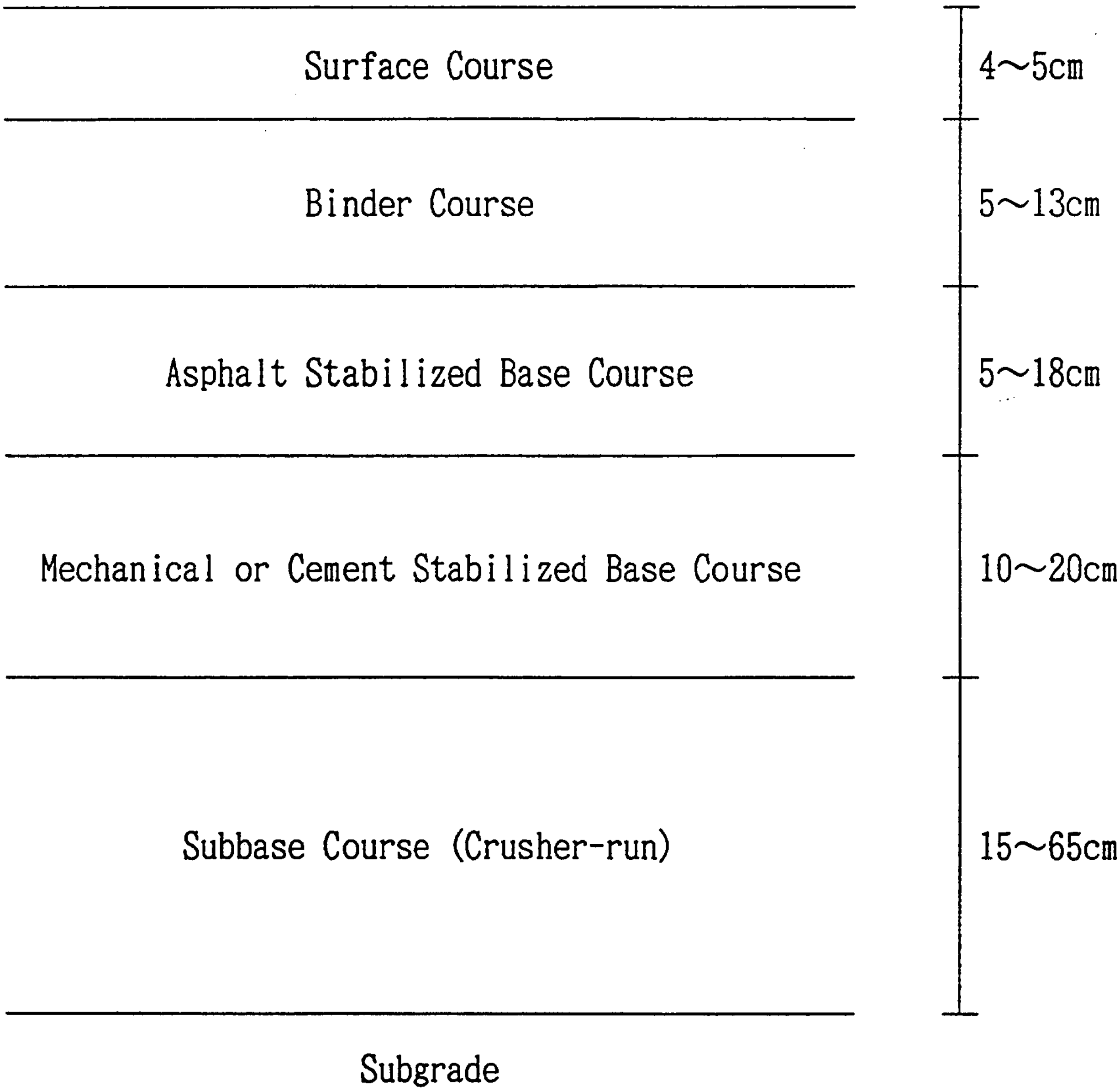


Figure 3. A pavement structure to be constructed at the selected testing sections.

Table 1. List of Japan's LTPP test pavements and their characteristics.

** All the test sections are tentatively assumed " WET " with " High " Traffic Rate.

Dist-rict	Code 94-	Route No.	Route Section's Name	Opened Year	Base Type	Primary Tier Subgrade	Primary Tier Traffic	Primary Tier Temp.	Primary Tier Mois.	Primary Tier AC Stiff	Secondary Tier A C	Secondary Tier ST-Base	Secondary Tier Subbase
							**		**	kg/cm²	cm	cm	cm
Hokkai-do	101	36	Shiraoi BP	1989	AC-ST	Fine	High	Freeze	Wet	56,750	17	18	50
	102	228	Kikonai BP	1989	AC-ST	Coarse	H.	F.	W.	50,300	14	12	55
	103	337	Zenibako Road	1990	AC-ST	F.	H.	F.	W.	50,983	17	18	65
Tohoku	201	13	Yamagata-kita BP	1988	AC-ST	C.	H.	F.	W.	62,419	17	8	20
	202	4	Shibata-BP	1989	AC-ST	C.	H.	F.	W.	56,217	15	10	30
	203	108	Wakuya BP	1990	AC-ST	C.	H.	Non-Freeze	W.	36,900	18	15	20
Kanto	301	246	Yamato-Atsugi BP	1988	AC-ST	C.	H.	N-F.	W.	51,980	15	10	40
	302	17	Fukaya BP	1989	AC-ST	C.	H.	N-F.	W.	63,583	15	10	25
	303	51	Sawara BP	1989	AC-ST	F.	H.	N-F.	W.	55,533	15	10	40
	304	4	Shin-Route.4	1990	AC-ST	F.	H.	N-F.	W.	51,350	15	10	40
Hoku-riku	401	8	Nagaoka-higashi BP	1988	AC-ST	C.	H.	N-F.	W.	46,020	15	10	10
	402	7	Shin-shin BP	1989	AC-ST	C.	H.	N-F.	W.	49,617	15	10	40
	405	8	Kurikara BP	1990	AC-ST	F.	H.	N-F.	W.	44,517	15	10	30
Chubu	501	23	Nansei BP	1988	AC-ST	C.	H.	N-F.	W.	48,965	10	10	50
	502	1	Numazu BP	1990	AC,CE-ST	C.	H.	N-F.	W.	63,783	15	10	30
	503	1	Kameyama BP	1990	AC-ST	C.	H.	N-F.	W.	41,183	15	10	50
Kinki	601	175	Ono BP	1988	AC-ST	F.	H.	N-F.	W.	60,098	10	10	15
	602	8	Fukui BP	1989	AC-ST	C.	H.	N-F.	W.	44,150	15	8	30
	603	161	Takashima BP	1990	AC-ST	C.	H.	N-F.	W.	47,183	10	10	20
Chugoku	701	54	Kamine BP	1989	AC-ST	C.	H.	F.	W.	51,717	15	10	25
	702	9	Hojo BP	1990	AC-ST	C.	H.	N-F.	W.	50,667	10	5	30
	703	188	Kudamatsu BP	1990	AC-ST	C.	H.	N-F.	W.	46,550	10	5	30
Shikoku	801	11	Matsuyama-higashi	1988	AC-ST	C.	H.	N-F.	W.	49,539	10	12	25
	802	11	Saijo BP	1989	AC-ST	C.	H.	N-F.	W.	43,200	10	10	20
	803	55	Tokushima-minami BP	1990	AC-ST	F.	H.	N-F.	W.	62,600	10	12	25
Kyushu	901	3	Okagaki BP	1989	AC-ST	C.	H.	N-F.	W.	50,667	15	10	25
	902	228	Higashi-taku BP	1990	AC-ST	F.	H.	N-F.	W.	70,117	10	10	30
	903	10	Shiida BP	1990	AC-ST	F.	H.	N-F.	W.	49,867	15	10	25

Table 2. The numbers of sampling design and cell identifications for Japan's GPS-2.

Factor Midpoints:

Freezing Index = 0 \
#200 Passing = 35 % \
85 KESAL/Year \

Moisture				WET								DRY							
Temperature				FREEZE				NO FREEZE				FREEZEE				NO FREEZE			
Subgrade Type				FINE		COARSE		FINE		COARSE		FINE		COARSE		FINE		COARSE	
Traffic Rate																			
#1 Binder Type	#2 Surface Stiffness	#3 Surface Thickness	Base #4 Thickness	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH
BITUMINOUS	LOW < 650 ksi	LOW	LOW								1								
			HIGH																
		HIGH	LOW						2		2								
			HIGH																
	HIGH ≥ 650 ksi	LOW	LOW						3		5								
			HIGH																
		HIGH	LOW		2		4		3		6								
			HIGH																
NON-BITUMINOUS	LOW < 650 ksi	LOW	LOW																
			HIGH																
		HIGH	LOW																
			HIGH																
	HIGH ≥ 650 ksi	LOW	LOW																
			HIGH																
		HIGH	LOW																
			HIGH																

CAUTION

All the test sections are tentatively assumed " WET " with " High " Traffic Rate.

#1 This is for a Treated Base. #2 This is for a Top Surface Course. ⟶ The Midpoint is 650 ksi. (=45,702 kg/cm²)
#3 This is a total thickness of AC Layers over Stabilized Base. ⟶ The Midpoint is 4.5 inches. (=11.25cm)
#4 This is a total thickness of Stabilized Base. ⟶ The Midpoint is 8.0 inches. (=20.00cm)

been translated into Japanese by the PWRI. The Japanese guidelines consist of the same six chapters as the *Data Collection Guide*:

1. Inventory Data

    a. Common data such as site of test section, name of highway
    b. Road data such as number of lanes
    c. Pavement structural data such as materials and thickness of each layer
    d. Materials properties data
    e. Others

2. Monitoring Data	Regular measurement of pavement performance such as cracking, roughness, rutting, and skid resistance
3. Traffic Data	Research on traffic volume and axle loads
4. Environmental Data	Research on air temperature, precipitation, etc.
5. Maintenance Data	Research on method, area, materials, cost
6. Rehabilitation Data	Research on method, scale, materials, cost for overlay, milling overlay or surface recycling in place

Japan's *Data Collection Guide* was distributed through each regional construction bureau to branch offices. All the collected data from the offices are to be sent through their bureaus to the PWRI.

Comparison of Test Methods

In order to compare the Japanese and United States' LTPP data, we must know whether the results from Japan's test methods are comparable to those from the United States. A comparison study between test methods used in the two countries was already conducted by the PWRI and Keizo Kamiya (1991). Parts of this study are included in this document.

Conduct of Field Material Sampling

Material sampling and in situ tests were conducted during the construction of each testing site. The material samples were sent to the PWRI, where the laboratory material tests, such as asphalt cement properties and resilient modulus, are now being performed.

Each 30 kg of construction materials and 10 kg of stabilizing materials were sampled for subgrade, subbase, base, binder, and surface courses at every testing site. Subgrade materials were obtained by digging 50 cm from existing subgrade surfaces. In order not to change their water content or other properties, each sample was tightly packed in a thick vinyl bag.

Twelve asphalt concrete cores with a diameter of 10 cm were taken every test site. The differences in core size between the cores taken in Japan and United States are not considered to be a significant factor for the test results.

Material Testing

The PWRI is testing the asphalt cement properties and resilient modulus. Other tests were conducted in construction procedures. The PWRI has obtained these test results.

Methodology According to the comparison study of test methods used in the United States and Japan, the degree of differences between test methods are classified into four levels:

1. Incomparable	A test method or test number designated by SHRP is completely different from Japanese practice
2. Non-Allowable	In a comparison of test methods, there could be differences in test results which are unacceptable
3. Allowable	Test methods appear to be comparable
4. No Difference	The SHRP test method or number is already used in Japan

Test methods not conducted in Japan but done in the United States are shown in table 3.

Table 3. Test methods not conducted in Japan but conducted in the United States.

SHEET No.	Sheet Title / Test Item	Prescription U.S.A.
(INVENTORY DATA)		
12.	Aggregate Properties	
10-13	Aggregate Durability	Table A.13
-14	Polish Value	AASHTO T 279 (=ASTM D 3319)
17.	Original Mixture Properties	
-6	Moisture Suceptibility	
	Test Results:	
-10	Tensile Strength Ratio	AASHTO T 283
-11	Retained Strength	AASHTO T 165 (=ASTM D 1075)
18.	Construction Data	

SHEET No.	Sheet Title / Test Item	Prescription U.S.A.
20.	Subbase Material Description	
-10	Calcium Carbonate Content	ASTM D 4373
22.	Subgrade Material Description	
2-4	Density of Cohesionless Free-Draining Soils	ASTM D 2049
-5	Soil Suction	AASHTO T 273
-6	Expansion Index	
7-8	Swell Pressure	AASHTO T 190 or ASTM D 2844 AASHTO T 258 (Method 1)
(TRAFFIC DATA)		
5.-7.	Vehicle Classification	FHWA 13-Class System

The test methods classified as non-allowable are shown in table 4. Methods that are allowable or have no difference are shown in table 5. These tables show that most of Japan's material test methods are comparable to those used in the United States.

Example Design of a Sample Plan As shown in table 4, Japan's resilient modulus test is considered to be different from the United States' test. The PWRI is investigating the significance of this difference.

Distress

The PWRI translated the *Distress Identification Manual for the Long-Term Pavement Performance Studies* (SHRP 1993) into Japanese, and distributed it to each regional construction bureau. This manual is now used at each testing site in Japan so that the distress survey is comparable with the United States' practice.

Equipment A manual 3-meter profilometer is used to determine the severity of rutting by in each regional construction bureau. Other distress modes are sketched and distress areas are measured.

Data Collection According to the comparison study on distress survey, table 6 shows the differences between procedures used in the United States and Japan. Japan omits polished aggregate. A distress survey is conducted annually by the technical offices under each regional construction bureau between September and November.

Rutting Measure the transverse profile every 20 meters (compared to every 50 feet [15 meters] in the United States)

Cracking Measure the area (m^2) or length (m) of each type of cracking at each distress level

Patching Measure the number and area of patches at each distress level (low, moderate, high)

Potholes Measure the number of potholes at each distress level (area and depth)

Shoving Measure the area of shoving

Bleeding Measure the area of bleeding at each distress level (low, moderate, high)

Ravelling and Weathering Measure the area of ravelling and weathering at each distress level (low, moderate, high)

Table 4. Test methods classified into "non-allowable".

SHEET No.	Sheet Title / Test Item	Prescription U.S.A.	Prescription JAPAN
	Subbase Material Description and Subgrade Data		
20- 8	Compression Test AASHTO ASTM T 167 D 1074 T 220 T 24 D 1633 T 234 D 2850	ASTM D 1633⟶ (Compression) ASTM D 558 ASTM D 559 ASTM D 1632 (Specimen)	JIS A 1216 P199 (Compression) JIS A 1210 P192 (Specimen) *1 Uncomparable
20-11 21- 2	California Bearing Ratio	AASHTO T 193 or ASTM D 3668	*2 Uncomparable
20-12 21- 3	Resistance Value	ASTM D 2844 (=AASHTO T 190)	*3 Uncomparable
20-13 21- 4	K-Value	AASHTO T 221 or ASTM D 1195 or AASHTO T 222	JIS A 1215 *4 Non-Allowable

*1 JAPAN makes test specimen while the U.S.A. uses sampled core. Curing Condition is different between ASTM D 1633 and JIS A 1216.

*2 JAPAN conducts Modified CBR for Subbase which is referred to ASTM D 1883 and JAPAN's Subgrade CBR Test Method has different content from the U.S.A's.

*3 JAPAN's Resistance Value is referred to ASTM D 1560.

*4 How to calculate K-Value is different between AASHTO T 222 and JIS A 1215.

SHEET No.	Sheet Title / Test Item	Prescription U.S.A.	Prescription JAPAN
	(LABORATORY MATERIAL TEST)		
	Original Mixture Properties		
	Resilient Modulus for Surface & Binder Course	ASTM D 4123 and SHRP P07	ASTM D 4123 Non-Allowable
	Specimen Diameter	4 inch	10 cm
	Testing Temperature	15, 25, 40 ℃	5, 25, 40 ℃
	Loading Frequencies	0.33, 0.5, 1.0	1.0
	Waveform Load	Haversine	Haversine
	Load Duration	0.1 sec	0.4 sec
	Rest Period	0.9 sec	0.6sec
	Loads	15℃ 35% 25℃ 20% of Indirect Tensile Strength 40℃ 5%	5℃ 100 kgf 25℃ 40 kgf 40℃ 10 kgf
	Indirect Tensile Test	SHRP P07	ASTM D 4123 P568 Non-Allowable
	Specimen Diameter	4 inch	10 cm
	Testing Temperature	25 ℃	5, 25, 40 ℃
	Loading Speed	50.8m/min	50m/min
	Loading Strip	A radius of curvature equal to the normal radius of the test specimen (ASTM D 4123)	Flat Plate

Table 5. Test methods classified into "allowable."

SHEET No.	Sheet Title / Test Item
	(INVENTORY DATA)
	Aggregate Properties
13-2	* Gradation
	(Bulk Specific Gravities)
13-3	Coarse Aggregate
13-4	Fine Aggregate
13-5	Mineral Filler
	Asphalt Cement Properties
14- 4	Specific Gravity of Asphalt cement
14- 5 15- 3	Viscosity at 140°F
14- 6 15- 4	Viscosity at 275°F
14- 7 15- 8	Penetration at 77°F

SHEET No.	Sheet Title / Test Item
14-10 15- 5	Ductility at 77°F
14-11 15- 6	Ductility at 39.2°F
14-13 15- 9	Penetration at 39.2°F
14-14 15-10	Ring and Ball Softening Point
15- 2	Thin Film Oven Test
	Original Mixture Properties
16- 3	Maximum Specific Gravity
16- 4	Bulk Specific Gravity
16- 7	Asphalt Content
16-15 16-17	Marshall Stability Marshall Flow
16-18 16-19	Hveem Stability Hveem Cohesionmeter Va

SHEET No.	Sheet Title / Test Item
	Subbase Material Description
19- 3	Atterberg Limits
19. 8-13	* Insitu Dry Density Insitu Moisture Content
19. 14-15	* Gradation * Hydrometer and Sieve Analysis passing 2.00mm
19- 6	Maximum Dry Density
	Subgrade Data
21- 6 - 7	* % Passing Sieve #40 * % Passing Sieve #200
21- 8	Plasticity Index
21- 9	Liquid Limit
21-12	Maximum Dry Density

SHEET No.	Sheet Title / Test Item
21. 14-25	Insitu Dry Density Insitu Moisture Content
22- 1	Relative Density
22- 9	% Finer than 0.02m
	(LABORATORY MATERIAL TEST)
	Subbase Resilient Modulus
	Subgrade Resilient Modulus

* A Test Number is not designated in the SHRP LTPP Data Collection Guide. This case was compared with some suitable test for the one conducted in JAPAN.

Table 6. Comparison of test methods for distress surveys, rut depth, and lane-to-shoulder dropoff used in the United States and Japan.

(MONITORING) 0:Allowable / Δ:non-Allowable

SHEET No.	Sheet Title / Test Item	Prescription U.S.A.	Prescription JAPAN	Difference no	①	②	③	④	⑤	** Remarks** ① Purpose ② Scope ③ Apparatus ④ Procedure ⑤ Report
1. 2.	Distress Survey			0						As for Crack, Patching, Pot hole, Shoving, Bleeding, Aging, Raveling and Pumping, JAPAN observes in accordance with Distress Id Manual. JAPAN omits polished aggregate.
3-9	Rut Depth		p941					0		③ ④ SHRP measures transverse profile. This data can be processed to provide rut depth measurements similar to those used in JAPAN.
3-14	Lane-to-shoulder Dropoff		p976					0		④ U.S.A. every 50 feet, JAPAN every 20m

Water Bleeding and Pumping Measure the number of water bleeding and pumping at each level (low, moderate, high)

Data Reduction Rutting depths at the inner wheel and outer wheel path are to be recorded at every 20 meters. Maximum, minimum, average, and standard deviation of rutting depth data for each path are calculated.

Other distresses are recorded by area or length in accordance with the level of distress.

Deflection

The PWRI will perform falling-weight deflectometer surveys for all the LTPP testing sites. Therefore it is possible to directly compare all Japanese deflection data.

Equipment The manufacturer of the PWRI's FWD is Kuab Co. Ltd. (Sweden). Until 1991, it had only four sensors positioned 0, 20, 45 and 90 cm from the loading plate. In FY 1991, the number of the sensors was increased to seven. These are positioned 0, 20, 40, 60, 90, 150 and 200 cm from the loading plate. The number of seatingdrops is one in Japan whereas three in United States. Testing load is 49.6 kN in Japan, while four load levels are used in the United States.

Data Collection Deflections and actual peak-loads are measured three times at every 20 meters (about 14 point/section), compared to every 7.5 m in the United States. Comparison of FWD test methods between Japan and the United States is shown in table 7. In Japan, there is only one testing level (data is stored only at deflection peaks using a testing load of 49.6 kN). This test result is considered comparable to the United States' test results at deflection peaks using a 53.3 kN testing load, and incomparable with the United States' test results using the other test load levels. Measurement is conducted annually between September and November.

Data Reduction A data reduction plan is now under way using a multilayer elasticity theory.

Table 7. Comparison of test methods for deflection measurements used in the United States and Japan.

(MONITORING)

O:Allowable / Δ:non-Allowable

** Remarks** ① Purpose ② Scope ③ Apparatus ④ Procedure ⑤ Report

SHEET No.	Sheet Title / Test Item	Prescription U.S.A.	Prescription JAPAN	Difference no	①	②	③	④	⑤
	Deflection Measurement								
	Falling Weight Deflectometer						O	O	

Item	SHRP	JAPAN
③ Manufacturer ③ Number of Sensors ③ Sensor Configuration	Dynatest Co, Ltd.(U.S.A.) 7 0, 20, 30, 45, 60, 90, 150cm	Kuab Co, Ltd (SWEDEN) 7 (4 until FY 1990) 0, 20, 45, 90cm until FY 1990 0, 20, 40, 60, 90, 150, 200cm since FY 1991
④ Measuring Points	25 feet interval	14 Points / Section
④ Data Stored	Deflection Peaks Deflection-Time History	Deflection Peaks
④ Drops used for Seating/ Point ④ Testing Load / Point	3 times at 53.3kN 4 Load Level(26.7, 40.0, 53.3, 71.7kN)	1 Time at 5000kgf 5000kgf(49.6kN)
④ Measuring Times	Deflection Peaks: 4 times / Load Level Deflection-Time History: 1 time / Load Level	Deflection Peaks: 3 times / Point

There is no significant difference of testing machine except the number of sensors. According to a comparison test between 7 sensors and 4 sensors in JAPAN, there was some difference in test result. The number of sensors is the same as in SHRP FWD Guide since FY 1991. The data obtained before this time is considered to be convertible in analysis; location of sensors and every deflection are to be requested in JAPAN's Data Sheet.

Equipment Calibration For data accuracy, the sensors (including displacement of each deflection detector), thermometer, and loading system are calibrated in May or June.

Profile

Equipment A manual 3-m profilometer is used to measure roughness. A transverse profilometer is used to measure rutting depth. Figures 4 and 5 show each profilometer. Measurement is annually conducted by each regional construction bureau. The PWRI is not coordinating each bureau's specification on profile measurement, so detailed specifications of equipment may vary among the bureaus. But this should not cause different test results.

Data Collection Distances from the road surface to a standard line of profilometer are measured at every 1.5 m for each wheel path to measure roughness. There is no specific walking speed for measurement, but the speed is recorded. A standard deviation will be calculated using the distances at every testing site. Distances from the road surface to a standard line of profilometers are measured across traffic lanes at every 20 m to measure rutting depth. Two peak values of transverse profile are considered to be rutting depths of inner wheel path and outer wheel path.

Profile testing is conducted by a technical office under each regional construction bureau between September and November. As shown in table 8, the United States' vehicle-based device obtains several indices, while Japan's manual device obtains only roughness. So far there has been no information on the degree of differences among those indices in Japan.

The PWRI is conducting a correlation study between the roughness which is obtained in the Japanese procedure and the International Roughness Index (IRI).

Table 8. Comparison of test methods for roughness used in the United States and Japan

(MONITORING)

O:Allowable / Δ:non-Allowable

SHEET No.	Sheet Title / Test Item	Prescription U.S.A.	Prescription JAPAN	Difference no	①	②	③	④	⑤	** Remarks ** ① Purpose ② Scope ③ Apparatus ④ Procedure ⑤ Report
	Roughness		p931				Δ	Δ	Δ	The following is a comparison of testing condition in accordance with SHRP Guide -lines.

Item	U.S.A.	JAPAN
③ Testing Machine	Surface Dynamics Road Profilometer Model 690DNC	3m Profilometer
④ Testing Method ④ Testing Site ⑤ Report	Moving Both Wheel Paths IRI, *1Mays Index, *2RMSVA , Slope Variance	 Both Wheel Paths Roughness
It will probably be necessary to develop correlations between JAPAN's Roughness measurement and IRI or other indices.		

*1Mays is a machine name.
*2RMSVA is short for Root Means Square Vertical Acceleration.

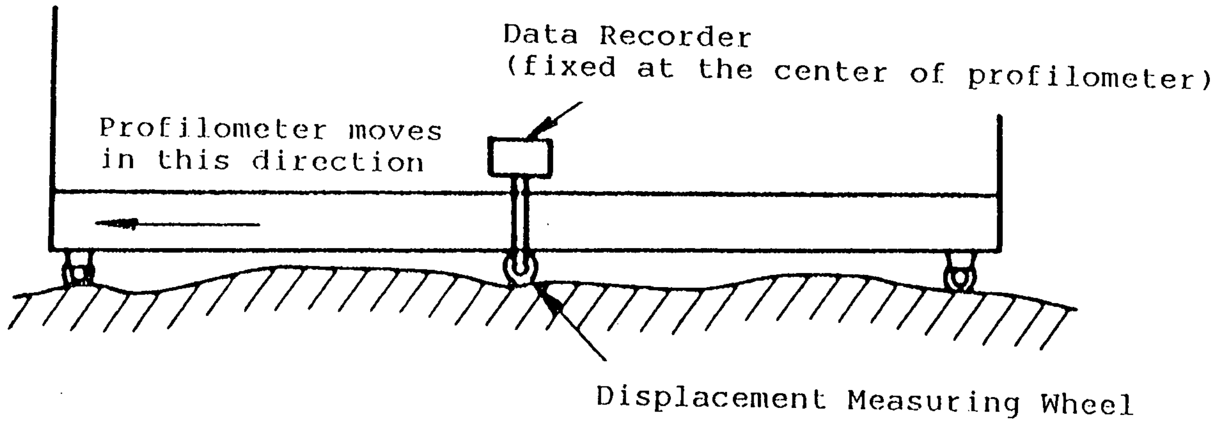


Figure 4. Manual 3-m profilometer.

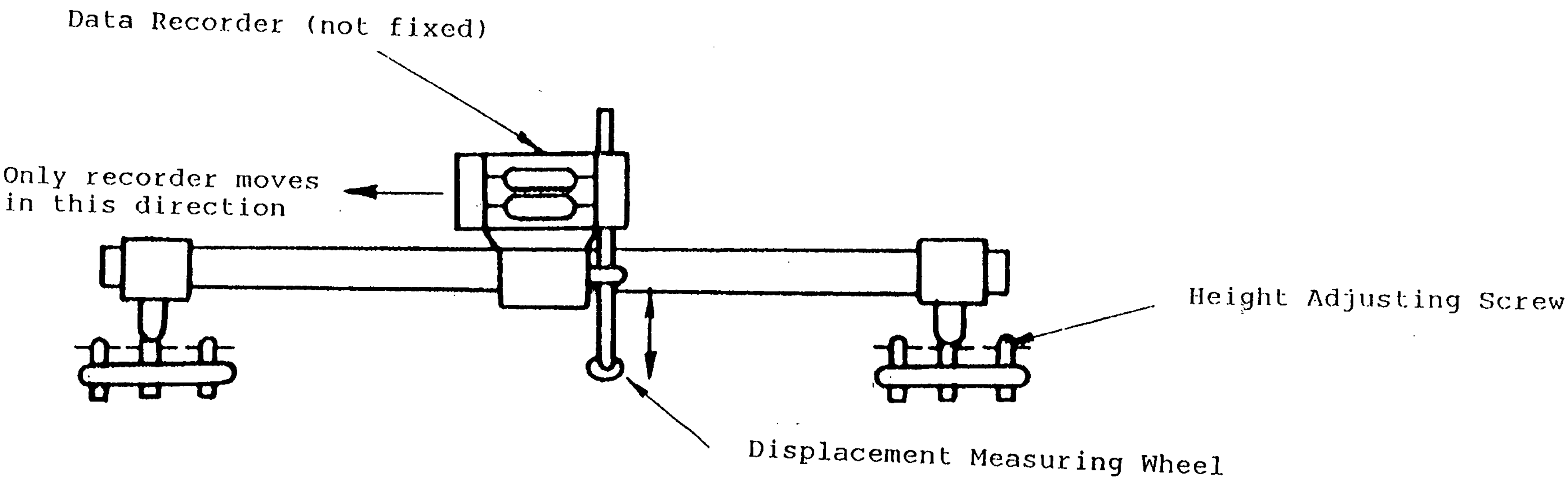


Figure 5. Transverse profilometer.

Data Reduction Roughness of every testing site in Japan is to be calculated by the following equation:

$$\sigma = \sqrt{\{\Sigma d^2 - (\Sigma d)^2 / (n-1)}$$

Where:

σ:	roughness (standard deviation, mm)
d:	distance measured between road surface and a standard line of a profilometer at every 1.5 meters (mm)
n:	the number of data

Maximum, minimum, average, and standard deviation of rutting depth at both wheel paths are calculated at every testing site.

Equipment Calibration Calibration is not conducted for these profilometers.

Skid Resistance

Equipment Each regional construction bureau performs measurements with a locked-wheel skid tester every 5 years. The PWRI performs skid measurements with a dynamic friction skid tester every year. The locked wheel skid testers meet ASTM's requirements. The manufacturer of the dynamic friction skid tester is Sunny Kogyo Co. Ltd. in Japan. This tester measures skid resistance with rubber pads attached to a disk. These are dragged over the wetted pavement surface while the disk is rotating horizontally. The size of this equipment is 540 mm × 590 mm × 380 mm, and the controller's size is 470 mm × 630 mm × 170 mm. The testing procedures for these devices are shown in table 9.

Data Collection Longitudinal skid (100 percent brake) and sideway skid (skid angle 15°) are to be measured using a locked wheel skid tester at the three velocities 20, 40 and 60 km/hr at every testing site Three points/site are to be measured at the center of the inner wheel path. Skid resistance is to be measured using a dynamic friction skid tester at disk velocities of 10, 20, 30, 40, 50, 60, 70 and 80 km/hr. The same three points/site evaluated with the locked wheel skid tester are to be measured using the dynamic friction skid tester. Air temperatures also are recorded. The testing season for both the locked wheel skid tester and the dynamic friction skid tester is between September and November. The correlation between data collected with the dynamic friction skid tester and the locked wheel skid tester is now under investigation by the PWRI.

Data Reduction One skid resistance (average of three measurements) at each speed is to be measured at every testing site.

Equipment Calibration Locked wheel skid testers are sent to the PWRI and calibrated every five years (the same intervals as measurement) to allow direct comparison of test results. The dynamic friction skid tester is not calibrated.

Table 9. Comparison of test methods for skid data used in the United States and Japan.

(MONITORING)　　　　O:Allowable / Δ:non-Allowable

SHEET No.	Sheet Title / Test Item	Prescription U.S.A.	Prescription JAPAN	Difference no	①	②	③	④	⑤	** Remarks ** ① Purpose ② Scope ③ Apparatus ④ Procedure ⑤ Report
1.	Skid Data									
- 6	Locked-Wheel Skid Test	AASHTO T242 or ASTM E 274	Locked-Wheel Skid Tester					O	O	JAPAN's Locked-Wheel Skid Tester is considered to meet ASTM.
			DF Skid Tester				Δ	O	Δ	

Item	U.S.A. ASTM	JAPAN Locked-Wheel S. T.	JAPAN DF Skid Tester
③ Structure of Machine	The tester measures skid resistance with a locked test wheel as it is dragged over a wet-ted pavement surface under constant load and at a constant speed while its major plane is parallel to its direction of motion and per-pendicular to the pavement.		This tester measures skid resistance through some rubber pads attached to a disk as they are dragged over a wetted pavement surface while the disc is rotating horizontally.
④ Type of Skid	Longitudinal Skid (100% Brake)	Longitudinal Skid (100% Brake) Sideway Skid (Skid Angle 15°)	
③ Tire			
Form	15 x 6" JJ rim	Rib tire, Smooth Tire	
Size	ASTM E 501	165-SR13	
Inflation Pressure	165 kPa	1.7kgf/cm² (167 kPa)	
Under-Trend Thickness	2.5mm	1.7mm at Slip Sign	
④ Wheel Load	4800 N (485kgf)	395kgf (3873 N)	
④ Velosity	40mph(flexible)	20, 40, 60 km/h	10, 20, 30, 40, 50, 60, 70, 80 km/h
④ Wetting Depth	0.5mm	0.5 ~ 1.0mm	0.5 ~ 1.0mm
④ Testing			
Frequency	Once / 2 years	Once / 5years	Once a year
Time	No Restrictions	September to November	
Site	2 Points/section at Center of Inner Wheel Path	3 Points/section at Center of Inner Wheel Path	
⑤ Report	SN SN=(F/W)x100 F, W:lb	Skid Resistance Coefficient: μ μ=(F/W) F, W:kg	

Skid Resistance Coefficient by JAPAN's Locked-Wheel S. T. is considered to be comparable with SN by U.S.A's although both are in different units. Correlation between data by DF T. and those by L.W.S.T. is investigated. A comparison test between them will be conducted under Piarc Technical Committee on Surface Characteristics in Belgium in 1992.

Traffic

Equipment Each regional construction bureau is responsible for traffic survey using a portable weighing mat (with piezo films) to measure axle loads and the number of axles. When a vehicle passes over the mat, pressure caused by each axle load of the vehicle changes the electrical resistance of the piezo films. The degree of this change is used to calculate the load. Most bureaus use Dynamat Co. Ltd. mats. Others use the ones made by Sakata Denki Co. Ltd., Japan.

Data Collection Each regional construction bureau conducts traffic volume counts one way in the same direction as GPS lanes using a manual counter. Wheel load measurements are obtained with a portable weighing mat only on the GPS lane. These surveys are simultaneously conducted from 7:00 a.m. to 7:00 a.m. the next day on a weekday in September or November.

The total traffic volume, total traffic volume of heavy trucks, axle configuration for heavy trucks, the number of axles, and each axle load are recorded at every test site.

Traffic Data Processing and Analysis Because Japan's traffic survey is conducted annually for twenty-four hours, data processing and analysis procedures are limited. For example, the total traffic volume is regarded as Annual Average Daily Traffic (AADT).

An automatic vehicle classification system is not used, so distances between two axles are unknown and vehicles can not be classified. Only the number of axles and each axle load are measured using a portable weighing mat. Because each measured axle load is regarded as a single axle load, all the axle loads are transferred to the number of equivalent 10-ton single axle loads by the following equation:

The number of equivalent 10-ton single axle loads $= \Sigma\{(P_i/10)^4 \times (\text{the number of } P_i)\}$
where P_i = measured axle loads (ton)

The load classification to be conducted in the United States and Japan is shown in table 10.

Equipment Calibration A portable weighing mat measurement requires calibration at a given point on every testing section before doing a twenty-four hour measurement. This is because measured data is affected by the condition of pavement on which the mat is attached. A truck of a known static weight of each axle load will run over the mat several times in order to determine the correlation between static and dynamic load at the given point. This result will be used to calibrate the twenty-four hour data.

General Monitoring Plan for the Future

Comparison studies for profile indices between roughness and other indices such as the International Roughness Index (IRI), and for skid measurements between the dynamic friction

Table 10. Comparison of test methods for truck axle load measurements by vehicle classification used in the United States and Japan.

(TRAFFIC)　　O:Allowable / Δ:non-Allowable

SHEET No.	Sheet Title / Test Item	Prescription U.S.A.	Prescription JAPAN	Difference no	①	②	③	④	⑤	** Remarks** ① Purpose ② Scope ③ Apparatus ④ Procedure ⑤ Report
9.	Truck Axle Load Measurements by Vehicle Classification								O	

Unit	U.S.A. pound	JAPAN ton	
Single Axle	w<3,000 3,000<w<30,000 w>30,000 adding by 1,000	0<w<14 adding by 1 ton	2 Axle Vehicle
Tandem Axle	w<6,000 6,000<w<60,000 w>60,000 adding by 2,000	Others: w>14 ton	3 and more Axle Vehicle
Tridem Axle	w<12,000 12,000<w<80,000 w>80,000 adding by 3,000		

skid tester and the locked-wheel skid tester are being conducted by the PWRI. Monitoring research and traffic surveys will continued in Japan until reconstruction or second rehabilitation takes place at every testing section.

SHRP-LTPP Information Management System

The PWRI obtained the Information Management System (IMS) software packages from SHRP in April 1992, and has been preparing to run it. Japan will modify the SHRP IMS software to add some new tables Japanese data and to accomodate for metric units. Japan will share the development of the International IMS with the other international users.

The aim of the international IMS for Japan is to minimize changes from the original SHRP IMS so that data from Japan and the United States may be compared.

The Netherlands

Pavement management is performed in the Netherlands at four administrative levels. The main road network comparable to the interstate system in the United States is managed at the national level by the Rijkswaterstaat (the Public Works Department of the Ministry of Transport and Public Works). The twelve provinces in the Netherlands are the next level of road authority: they manage all major arteries not covered by Rijkswaterstaat. The third level are the municipalities, managing both urban roads and non-urban roads of local importance. The fourth level of pavement management is typical for the Netherlands: a number of "waterschappen" (Water Control Boards) is responsible for the management of rural roads.

All four levels of road authorities participate in the Foundation CROW (Center for Research and Contract Standardization in Civil and Traffic Engineering), which performs a stimulating and coordinating role in pavement research in the Netherlands. For CROW, the United States' SHRP initiative and its quest for international participation were the main incentives in 1988 to set up a Steering Committee to investigate the need for participation of the Netherlands in SHRP. The Committee performed an inventory of research needs in the field of pavement management at all four administrative levels. Although pavement management systems were developed and implemented in the Netherlands as early as 1980, all four levels of road authority clearly favored participation in SHRP. Participation would open the way for application of SHRP's results in the Netherlands, could produce an update of current pavement management systems, and a differentiation of current systems to cater to the specific needs of all four levels of road administration.

Two conclusions were made from this inventory. First, active participation in SHRP was strongly recommended. Second, the Steering Committee concluded that to best solve the pavement management problems identified by the inventory, a full-scale, national Strategic Highway Research Program focusing on long-term pavement performance would be required. Hence, the decision was made to participate in SHRP with a national research project of sufficient magnitude to independently solve Dutch problems in pavement management. This project is structured in a way very similar to SHRP's LTPP study, to permit extensive exchange of data and research findings.

After reaching the above conclusions, the Steering Committee commissioned a joint venture of three major Dutch pavement management consultants to draft the research plans for SHRP-NL. The resulting blueprint for SHRP-NL was published in 1990.

Objective of Study

SHRP-NL focuses on pavement management. The inventory of research that needs to be performed showed two main topics of interest: the development of distress models and the development of maintenance and rehabilitation strategies. SHRP-NL deals with flexible pavements only, since rigid pavements are quite rare in the Netherlands.

Project Recruitment and Approval

The plans for SHRP-NL were first discussed with the United States counterparts at the SHRP Midcourse Assessment Meeting at Denver, Colorado in August of 1990. Then, a more in-depth discussion was arranged. Govert Sweere and Joop van Zwieten of SHRP-NL spend a week at SHRP Headquarters in Washington, DC to meet SHRP staff and discuss the SHRP-NL experimental designs and test methods in full detail.

Experimental Designs and Sampling Frame

The SHRP-NL LTPP project focuses on pavement management. Here, the pavement authority is faced with basically two questions: is rehabilitation required for a given pavement? if so, what rehabilitation is required? Annual broad Visual Distress Surveys at the network level are the authority's main tool for establishing which pavements need rehabilitation, while detailed Visual Condition Surveys and falling- weight deflectometer (FWD) tests are used for assessment of the pavement condition at the project level.

To further develop these pavement management tools, SHRP-NL will perform long- term pavement performance studies on two main groups of test sections. The first group involves sections that did not get major rehabilitations for at least five years before the start of SHRP-NL and will not get such rehabilitation during the five year monitoring period of SHRP-NL. On 144 of such sections, the development of pavement distress under the influence of traffic and climate is be monitored on an annual basis. The second group of test sections involve pavements that did get major rehabilitation in the initial phase of the SHRP-NL project. Here, the condition of the pavement prior to rehabilitation, directly after that and further on an annual basis will be monitored. Two types of rehabilitation are involved here: structural maintenance (asphalt concrete overlays) for pavements showing the fatigue type of distress and wearing course maintenance for pavements with distress modes such as ravelling and rutting. In all, this part of SHRP-NL involves studies on 120 test sections.

The 144 test sections in SHRP-NL used for the development of visual distress models were selected using an experimental design very similar of that of SHRP's projects GPS-1 and GPS-2. Key factors in selection of the test sections are type of subgrade, type of base, asphalt concrete thickness and traffic loading. Two types of subgrade are distinguished: clay/peat, and sand. For the base course, four factor levels are distinguished: no granular base ("full depth asphalt"), granular base, self-cementing granular base (materials such as crushed concrete and blast furnace slag that show an increase in stiffness with time) and bound base. Asphalt concrete thickness is incorporated in the experimental design at three

levels: thickness < 14 cm; thickness between 14 cm and 24 cm; and thickness > 24 cm. Traffic intensity is dependent on asphalt concrete thickness, ranging from less than 2,500 vehicles per day (total cross section) for the weakest constructions (asphalt thickness < 14 cm) to more than 60,000 vehicles per day for the strongest constructions (over 24 cm of asphalt concrete on bound base). As was done in SHRP, traffic was defined in terms of rate (vehicles per day) rather than accumulated standard axle loads to provide a good distribution of both pavement age and traffic. Finally, in the experimental factorials obtained using the above key factors, separate columns are entered for normal dense asphaltic concrete wearing courses and for pervious asphalt wearing courses. This is deemed necessary since visual distress surveys on the two types of wearing course yield different results. Therefore, the data for the two types of wearing course cannot be mixed in the analysis and, hence, separate sets of data are required. In total, the above experimental design leads to 144 test sections.

The 120 test sections for the rehabilitation effectiveness study were selected using experimental designs similar to those used in the GPS-6B (new AC overlay on AC) and SPS-3 (maintenance cost effectiveness) studies of SHRP. For the overlay study, key factors are visual condition prior to overlay, surface curvature index (SCI) from deflection measurements, the stiffness of the pavement foundation (again obtained from deflection measurements) and depth of cracking. Factor boundaries are medium/poor for visual condition, low/medium/high for SCI, low/high for stiffness of pavement foundation and through wearing course only/through total AC for depth of cracking. Again, separate columns are incorporated in the experimental design for dense asphalt concrete and previous asphalt concrete wearing courses. In all, this part of SHRP-NL involves 72 test sections.

The rehabilitation effectiveness study for wearing courses involves four widely used maintenance measures, being single and double surface treatments, stone mastic asphalt and slurry seals. For each treatment, SHRP-NL incorporates 12 test sections. Key factors in the experimental design are visual condition prior to maintenance (at levels medium and poor) and traffic intensity (at levels high, medium and low). In all, 48 test sections are involved in this part of SHRP-NL.

Environmental Factors

The Netherlands is a small country, measuring some 350 km in length and some 150 km in width. Obviously, a subdivision of the Netherlands into climatic regions as done in SHRP was not required. The whole country enjoys a mild, marine type of climate, with an annual precipitation of 750 mm. The number of days with subzero temperatures is limited to 10-20 per year.

Pilot Study Testing

Because of the size of the SHRP-NL project, considerable time was required to draft the research plans and to generate the required funding. This caused the Netherlands to join the SHRP effort rather late in October of 1990. The pilot studies in other participating countries

were at that time well underway. Hence, the Netherlands opted for starting directly with its full scale LTPP program.

Data Collection Program

Conduct of Field Material Sampling

The SHRP-NL test sections are 300 m long. This length was chosen to comply on the one hand with the standard length of 100 m at which visual distress surveys are conducted in the Netherlands and on the other hand with the SHRP section length of 150 m (500 feet). The first common denominator of 100 and 150 m is the 300 m SHRP-NL section length.

In compatibility with SHRP, the Coring and Sampling at the sections is performed outside the 300 m section. Both at the approach end and the leave end of the section 25 extra meters of section length are allocated for field materials sampling. At either end, six cores are taken from the asphalt concrete (four cores of 150 mm diameter for general materials testing and two cores of 100 mm diameter for resilient modulus testing). Bound bases are also cored, whilst unbound granular bases are denominated on site. Soil exploration boring is performed at one 150 mm core hole at either end of the section; soil samples are taken at 1.5 m and 2.5 m depth. Finally, Dynamic Cone Penetrometer tests are performed at one 150 mm core hole at either end of the section.

Materials Testing

The general inventory materials testing will involve standard tests for mixture properties such as density, bitumen content, percent air voids, etc. More detailed materials testing to be performed depends on the distress mode of the particular test section. For the sections where fatigue types of distress are predominant, materials testing will focus on determination of resilient moduli of the asphalt concrete to obtain reference data for stiffness in FWD backcalculation. For sections with predominant wearing course distress, materials testing will focus on determination of mixture and binder properties. Materials testing is scheduled to start in the summer of 1992.

Distress

Equipment SHRP-NL performs annual distress surveys on it 264 test sections. To maintain conformity with current pavement management practice, both broad and detailed manual visual distress surveys are performed. To obtain a permanent record of the distress, the Automatic Road Analyzer (ARAN) is used to make video images of the pavement surface.

The manual visual distress surveys are performed in full conformity with the Distress Identification Manual published by SHRP-NL's parent organization C.R.O.W. in 1987. This procedure was opted for rather than the SHRP procedure, since it has been implemented in the Netherlands at all levels of road authority. Use of the CROW procedure opens the

possibility for SHRP-NL to use historical data on distress from the archives of the participating road authorities. This is a major advantage over the situation in the United States, where SHRP had to start from scratch and therefore lacks well-organized historical data on distress. The CROW procedure is very similar to the distress identification procedure of SHRP, in the sense that the same types of distress are measured and recorded in very similar factions. The main difference lies in the meaning of the terms "light", "modest" and "severe" by which the distress is characterized. Thanks to the overall better condition of roads in the Netherlands (and Western Europe as a whole) distress considered to be "modest" in the CROW procedure may be marked as "light" in the SHRP procedure. To separate the distress data measured by the two different procedures, the SHRP-NL distress data are stored in separate tables in the International Information Management System (IIMS). A conversion table can later be developed to transform the SHRP-NL data into United States-compatible data or vice versa.

Automatic distress surveys are performed annually using the Automatic Road Analyzer ARAN. Three video cameras mounted on a Chevrolet van record the overall road image (by one camera through the front screen) and the detailed pavement surface image (by two cameras mounted at the back of the van). The images are stored on video tape, together with location information. To complement the location information generated by the ARAN, SHRP-NL uses a painted grid on the pavement surface, which is video logged by the ARAN. For the time being, the ARAN video tapes are merely used as a permanent record of the distress situation for each of the survey years. If need be, the tapes can be later run through the distress analyses procedure for the ARAN, to obtain distress data per 100 m subsection.

Data collection As noted above, both the manual and automatic distress surveys are performed on an annual basis on all 264 SHRP-NL sections. The surveys are performed between mid-April and mid-May, being after the occurrence of winter damage and prior to yearly maintenance.

Data reduction Adhering to the "truth in data" concept, visual distress data are stored in full format, without data reduction. The distress drawings made during the manual surveys are stored in hard copy and the video tapes from the ARAN are also stored. The data from the distress tables from the manual surveys are stored in the IIMS.

Deflection

Equipment Falling-weight deflectometer tests for SHRP-NL are performed using Dynatest 8000 equipment, in conformity with SHRP. In the section allocation phase of SHRP-NL, the Lacroix deflectograph was used to check section homogeneity. The deflectograph was preferred here over the FWD for reason of its much higher density of measurements (generating deflection bowls in both wheel tracks at 6 m intervals).

Data collection Falling-weight deflectometer tests are performed on an annual basis on a selection of SHRP-NL's 264 test sections. Those sections from the GPS-1 and GPS-2 types of sections that show visual fatigue distress are incorporated in this selection, as are all 72

sections from the GPS-6B group of sections (new AC overlays on AC). For the latter group, additional FWD measurements are performed prior to and directly after construction of the overlay.

The measurement procedure for FWD testing is in conformity with the SHRP procedure, with the exception of the levels of loading applied and the geophone setting. The load levels are set at 25, 50 and 75 kN, versus 6,000, 9,000, 12,000 and 16,000 lbs in the United States (26.7, 40.0, 53.3 and 71.1 kN, respectively). Geophone distances are 0, 300, 600, 900, 1200, 1500 and 1800 mm versus 0, 8, 12, 18, 24, 36 and 60 inches in the United States (0, 203, 304, 457, 610, 914 and 1524 mm respectively).

At each test section, test stations are in both the outer wheel track and at midlane, with spacings of 20 m. Hence, per section, 30 stations are measured.

The data recording procedure is in conformity with the SHRP procedure: for the first three blows per load level, only peak data are stored, while for the fourth blow, full load and deflection history data are stored.

Data reduction Adhering again to the "truth in data" concept, the full FWD data are stored in the IIMS, while summary data for convenience in viewing and analysis are obtained from the measured data using the SHRP data filter and data load programs.

Equipment calibration The Dynatest 8000 equipment is used as calibrated by the manufacturer. The equipment is sent back to the manufacturer at regular intervals for recalibration.

Profile

Equipment Profile measurements are performed by SHRP-NL using the ARAN, which incorporates an ultrasonic system for measuring the cross profile of the pavement coupled with a inertia system to obtain a longitudinal profile. It should be stressed here that, although different equipment is used for profile measurement, the fundamental data generated by the ARAN system (being the X-Y-Z coordinates of the pavement surface) can be easily interchanged with the SHRP profile data from the KJ Law profilometer, which has a similar fundamental format.

Data collection Profile measurements are performed at all 264 SHRP-NL sections on an annual basis, in the same period as the distress and FWD measurements.

Data reduction The full ARAN profile data are stored in the IIMS, using data load programs developed by SHRP-NL (SHRP does not use the ARAN and hence has not developed the required software). Further, summary data are generated by the data load software for convenient viewing and analysis.

Equipment calibration The ARAN profile measuring system is calibrated weekly by the operator using the calibration equipment provided by the manufacturer.

Skid

SHRP-NL performs no skid measurements.

Traffic

Contrary to the situation in the United States, the pavement authorities in the Netherlands have extensive traffic data collection programs. These programs are executed mainly to establish data on amount of traffic by way of pneumatic axle counting devices. Information on types of vehicles is obtained by visual surveys at the sites of the pneumatic equipment. The available equipment is rotated over the whole road network over a period of a number of years. This procedure has been in practice for a large number of years to date, generating rather detailed traffic estimates for the road network. SHRP-NL uses site-relevant information supplied by the road authority.

General Monitoring Plan for the Future

SHRP-NL's funding stretches till October of 1995. Monitoring will be executed on an annual basis until that date.

SHRP-LTPP International Information Management System

The Information Management System (IMS) developed by SHRP is a comprehensive, user friendly system dedicated to the data collection and storage of the SHRP LTPP study. However, the system is clearly dedicated to the work in the United States and Canada. The IMS uses U.S. Customary units, whereas the rest of the international pavement community uses SI units. Further, the IMS allows for storage of SHRP compatible data only. Profile data from the ARAN, for instance, cannot be stored in the SHRP supplied IMS, although they are basically very much compatible with the United States' profile data from the KJ Law profilometer. Thirdly, the levels of given parameters may differ from one country to another. As noted above, "modest" visual distress may mean something different in Europe as in the United States.

To deal with these differences, SHRP-NL has developed the Dutch Information Management System (DIMS) from the IMS supplied by SHRP. DIMS allows for storage of SHRP-compatible data in SI units and for storage of non-SHRP-compatible data, such as the ARAN profile data. The overall compatibility between DIMS and the IMS has been carefully safeguarded. Extensive discussions in the IIMS User Group have generated a set of rules for adapting the IMS to local needs, while maintaining compatibility between the various international systems. DIMS is the first example of such a system. The development of DIMS was completed in May of 1992, after which the first set of SHRP-NL data was

loaded. The first transfer of data to the IIMS at the Transportation Research Board in Washington will take place later in 1992.

Conclusion

SHRP-NL currently is the largest SHRP program outside the United States. From its 264 test sections, SHRP-NL will generate sufficient performance data to allow for development of distress models based on Dutch data only. This approach will ensure that the SHRP results obtained in the Netherlands will be compatible with the local pavement management systems. Looking ahead at implementation at the end of SHRP, this compatibility was deemed essential by SHRP-NL's funding organizations when the research plans for SHRP-NL were drafted. On the other hand, the experimental designs and data collection procedures are very similar to those of SHRP. Therefore, extensive exchange of research methods and findings has taken place from the onset of SHRP-NL an will continue throughout the extend of the programs.

Lagging a comfortable 2.5 years behind, SHRP-NL has greatly benefited from the experience of its United States counterparts in starting up and running this major research effort. The help provided by the SHRP staff in Washington has allowed SHRP-NL to gather its 264 test sections, draft its test protocols, perform its first round of monitoring and set up its local version of the Information Management System in a period of 1.5 years. As SHRP-NL begins to interpret the data, it will continue to exchange information, experience and research findings with its United States counterparts. SHRP-NL has noted well the commitment made by the Federal Highway Administration to continue all of the avenues of international cooperation built up by SHRP in the post-SHRP era. With the major challenges of data interpretation and implementation of the research findings ahead, SHRP-NL looks forward to maintaining strong cooperation with its United States counterparts.

The Nordic Countries

The Nordic countries (Finland, Denmark, Norway, Sweden) have actively participated in the SHRP-LTPP study since the beginning of the program in 1987. Cooperation between SHRP and the Nordic countries is based on information exchange and parallel GPS studies.

Exchange of information is accomplished by two methods: an international coordinator in each of the four Nordic countries and a loaned staff person representing the four Nordic countries at SHRP. Since 1986, a Nordic staff person has been assigned to the SHRP office in Washington DC. Each of the four countries took turns sending loaned staff; each loaned staffer worked at SHRP for a period of one year. This arrangement will continue until SHRP ends.

The Nordic countries formed a Nordic SHRP-LTPP project group with a representative from each of the four National Road Research Laboratories. The task for the group is to coordinate and ensure that the joint project is progressing according to plans. Each member of the group is in charge of the experiment in the respective country.

The Nordic countries participate in the GPS-1 experiment (AC on granular base) with test sections in each of the four countries. In addition to these experiments, GPS-6 (AC overlay on AC) experiments are carried out in Finland.

The objectives of the parallel Nordic SHRP-LTPP study are to:

- determine the factors effecting pavement performance
- develop pavement performance models for the Nordic environment
- establish the Nordic long-term pavement data base (IMS)

Selection of Test Sections (GPS-1)

The LTPP experiment in United States is designed to represent conditions within the North American continent. To meet the Nordic requirements, it has been necessary to modify the sampling plan (figure 1). The Nordic sampling plan can be considered a subsection of the sampling plan for the United States.

Figure 1 shows that the Nordic countries fall into the climatic zone described as wet-freeze in the American study. However, the temperature factor has two levels (medium, high) because of the importance of environmental effects on pavement performance. AC stiffness is not the major design factor because most of the stiffness values are quite close to each other for typical AC overlays (values are close to the SHRP's factor midpoint).

Base Thickness	AC Stiffness	AC Thickness								
Moisture			Wet							
Temperature Freeze			Low				Medium			
Subgrade Type			Fine				Coarse			
Traffic Rate			Med.	High	Med.	High	Med.	High	Med.	High
High	Low/ High	Low								

Figure 1. The Nordic sampling plan for GPS-1 experiment.

Typical pavement structures have a thin AC layer combined with thick unbound layers due to the frost protection requirements. This is illustrated in figures 2 and 3, which show the distribution of thicknesses of AC and unbound layers in Finland for GPS-1 sections. The average thickness of an AC layer is 76 mm, and an unbound layer is 905 mm.

The Nordic countries followed as closely as possible SHRP's criteria for selection of test sections. The objective was to find two test section for each of the cells in the sampling frame and that the two test sections came from different countries. The present number of sections selected for the Nordic GPS-1 study is 33 (Denmark 7, Finland 18, Norway 5, and Sweden 3). In addition, Finland has selected 28 GPS-6 test sections.

Data Collection

The Nordic countries provide data obtained with the same type of equipment and the same procedures as used by SHRP to correlate with the LTPP studies.

The dependent variables of performance models consist of pavement profile, deflection of response to load and pavement surface condition. True profiles of test sections are measured using road-surface-monitoring vehicles available in each country. Information can be processed to calculate the International Roughness Index (IRI) values for each test section. Deflection measurements are carried out with falling-weight deflectometers manufactured by Dynatest (Finland, Denmark, Norway) and KUAB (Sweden). Calibration of the Dynatest and KUAB

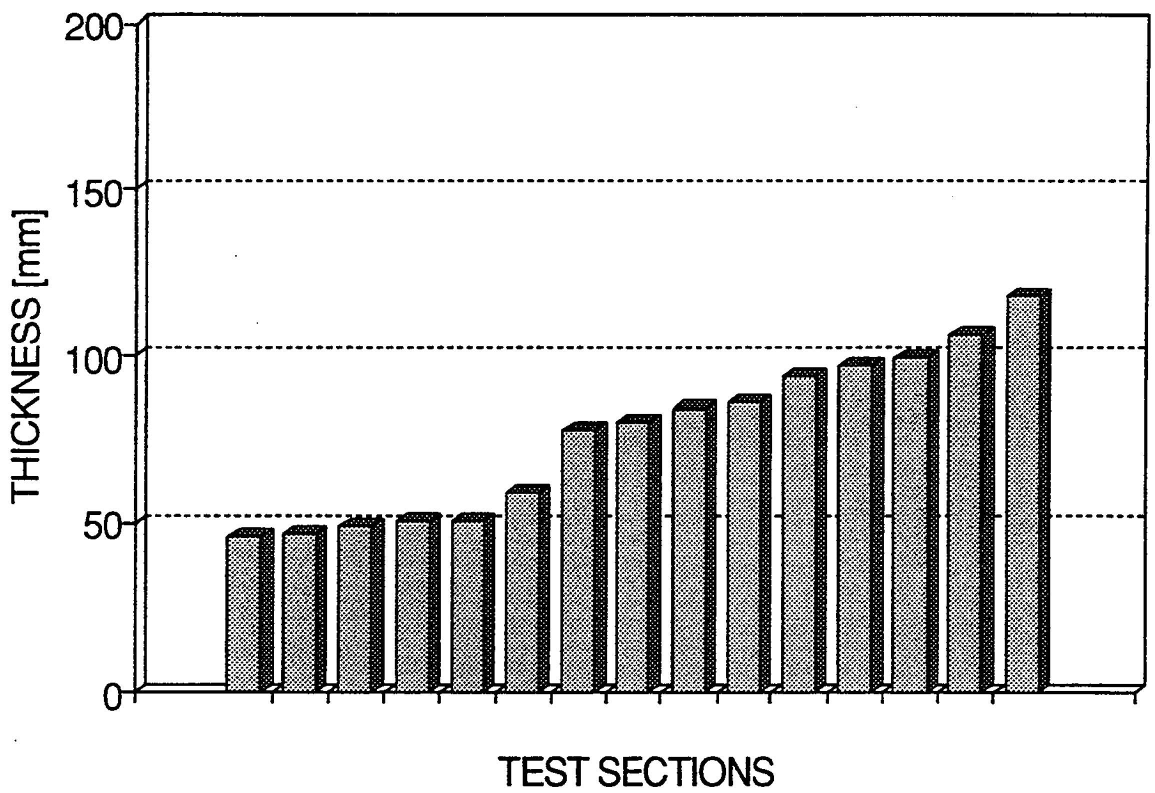


Figure 2. Thickness of AC layer in Finland (GPS-1).

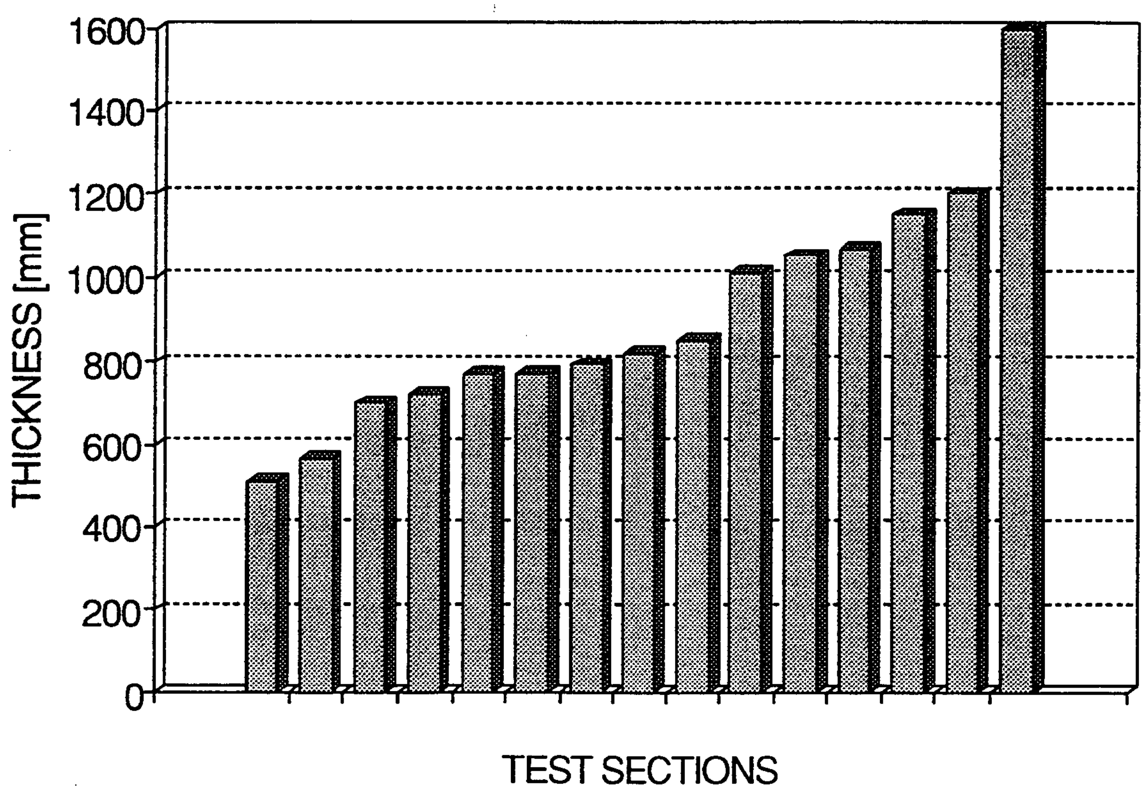


Figure 3. Thickness of unbound layers in Finland (GPS-1).

equipment has been conducted in the field on LTPP test sections located in Sweden. Surface condition is evaluated visually according to the *Distress Identification Manual for the Long-Term Pavement Performance Studies* (SHRP 1993) on an annual basis.

The other data collected from the test sections are related closely to pavement performance. This ensures that data collection costs are reasonable and that all the necessary information is available for data analysis.

The following data elements are collected from all the Nordic GPS-1 test sections:

layer thicknesses:	AC surface unbound base unbound subbase
layer stiffness:	AC surface unbound base unbound subbase subgrade
age and traffic:	age of pavement number of vehicles axle loads cumulative number of ESALs
AC mixture properties:	aggregate gradation asphalt grade viscosity (original property) penetration (original property) asphalt content (original property) percent air voids (original property)
base/subbase material:	classification gradation percent compaction in situ moisture content
subgrade:	classification gradation plasticity index in situ moisture content frost susceptibility classification
environmental and temperature data:	freeze index precipitation temperature

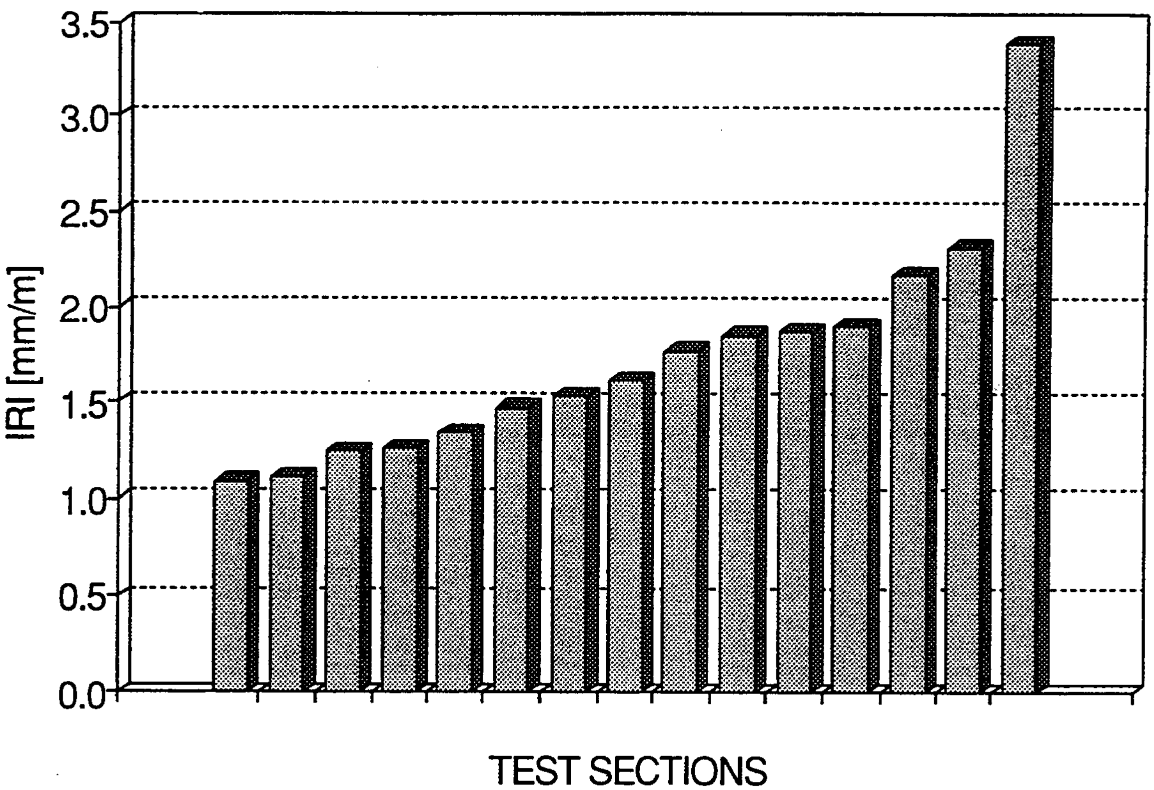


Figure 4. IRI values (mm/m) of GPS-1 test sections in Finland (GPS-1).

Figure 4 shows an example of the roughness distribution of GPS-1 test sections in Finland. The IRI value varies between 1.0 to 3.5 mm/m (average of 1.73 mm/m).

Database

All data are stored into the Nordic Information Management System (N-IMS). It is a copy of the SHRP IMS that has been modified according to SHRP's guidelines to meet the Nordic requirements. The database is located at the Technical Research Center of Finland from which data are transferred to the database at the Transportation Research Board in Washington DC.

Data Analysis

The results of the future analysis of performance data from the Nordic test sites can be used in an evaluation of the performance models developed from data measured at the LTPP test sites in United States. This will give an indication of the overall validity of the United States' models and on pavement deterioration theory in general. In addition, it will be possible to use the Nordic data to correlate the United States models to Nordic conditions.

The comparison of the Nordic and the United States data will extend the factor space, or the range of test variables, to conditions beyond those of both participating organizations. Also, United States data might be used to fill the vacant cells of the Nordic experiment.

Participation in the Nordic LTPP

Although the Nordic countries participate in the LTPP program with a cooperative study, each of the individual countries can use the results of the study as they find best suitable. This is illustrated by the following examples from Norway and Sweden.

Norway

Five GPS-1 experiment sites are located in Norway. This report describes the measurements scheduled for 1992.

Data collection

Field measurements The following measurements were carried out on the test sections:

- deflection measurements;
- roughness measurements;
- frost penetration; and
- distress survey.

Deflection measurements were carried out using a Dynatest 8000 FWD. Normally the test sections were measured twice a year to investigate seasonal variations but in 1992, FWD measurements were carried out only once due to budget limitations.

Roughness measurements and the distress surveys were carried out once a year, and frost penetration was measured once a week in the spring.

Material sampling Material sampling was carried out in June 1991 according to the SHRP procedure, but the following activities were excluded:

- 6- and 12-in. diameter coring of asphalt concrete
- 6- and 12-in. diameter augering of unbound base, subbase and subgrade
- split spoon sampling and thin-walled tube sampling from the subgrade

Augering of the unbound base, subbase and the upper 12 in. of the subgrade will be carried out next year. The remaining activities in the material sampling program will be discussed in the Nordic SHRP-committee, and the time schedule will be fixed later.

Traffic Data Collection Piezoelectric cables are used for automatic vehicle classification (AVC) and weigh-in-motion (WIM). The development of the software for the cables is in the final process. Thus, installation of the piezoelectric cables were limited to only one test section in 1992. The remaining test sections will be installed with WIM/AVC in 1993.

The traffic data collection handbook provides three levels for the monitoring phase. In Norway the minimum level was selected:

- a full year of AVC;
- four weeks of WIM, over the year.

Information Management System

The Nordic database is located in Finland at the Technical Research Center of Finland, Thus, all data is sent to Finland for implementation in the common Nordic IMS Data base.

Sweden

Sweden's road network consists of some 400,000 kilometers of roads, of which 100,000 are maintained by the state (National Road Administration) and 50,000 kilometers maintained by municipalities. The expenditure for bituminous surfacing overlays accounts for some 1.5 billion Swedish kronor a year (200 million European Community units, 250 million United States dollars).

Money allocated should be used such that you get "the best value for money spent." This, in respect of not only the road administrator but also the road users who are very much affected by the condition of the roads.

Within the planning process, the horizon being three to five years, the road engineer must select not only the type of overlay but also the timing. There is a general feeling that too little money is available, which leads to very thin overlays at very spaced intervals.

Today's planning process is mainly based on empiricism. Through the years, experience has been gathered about the effectiveness of different overlays in different situations. However, the need for a more objective and precise way to make the forecasting of the different overlays' performances is now more often stressed.

Therefore, at the request of the National Road Administration, the Swedish Road and Traffic Research Institute started a project in 1983 for the development of performance models. This project has an annual budget of 1.5 million Swedish kronor ($24,000 US), 0.1 percent of the maintenance expenditures.

Objective of the Research

The objective is to develop performance prediction models to be used to plan overlays on the project level. The models should help the engineer select the most appropriate overlay at the right time. Also, they should make it possible to predict performance (such as rutting and evenness) over time.

Design of the Experiment

A choice was made to use sections of the existing road network for the necessary data collection. The following criteria were adopted for the site selection process:

- two of the most common pavement types—bituminous courses (wearing, binder, and possibly base) on gravel and on crushed stone bases and subbases;
- traffic from 500 to 10,000 AADT;
- subgrade should be either frost or non-frost-susceptible;
- constructed according to guidelines;
- Near a first overlay.

It also was decided to make the sections fairly short—100 m—and to have an average of ten sections per site. The sections should be located in either cut or fill, avoiding transit sections.

The sections should be spread geographically over Sweden but with a "gravity point" closer to the more-trafficked south of Sweden. With this distribution, different climatic conditions would be covered—freeze-thaw as well as more stable winter climate.

Selection of Sections

Selection of sections started in 1984 with some 160 sections distributed over 13 projects. More sections have been added. At present, monitoring is performed on 469 sections on 41 projects. Projects that require more extensive measures have been included. The standard treatment for the majority of the first selected sections was levelling plus surface dressing (chip seal). Also, "non-built" roads and those with more than one overlay have been included.

Data Collection Program

Information about soils, materials, construction, etc. was drawn from existing records.

The monitoring program consists of:

- Evenness (laser RST);
- Cross-profile (profilograph and laser RST);
- Texture (laser RST);
- Deflection (KUAB falling-weight deflectometer).

Visual inspection is done for cracking (load and non-load related) and other distress types. Traffic data is collected as a periodic traffic count with vehicle classification included.

The frequency of data collection is varied. During the first years, data such as deflection was collected four times to cover seasonal variation. Now, FWD data is collected mainly (for sections monitored for some years) before and after an overlay. Samples of pavement materials are tested.

Weather stations operated by the Swedish Meteorological Institute provide climatic data.

The minimum level of monitoring is a visual inspection and laser RST measurements.

Data handling

A large amount of data is generated. Therefore, a PC-based relational database has been developed. There are 10 parallel data bases in the relational data base.

Model Development

When using existing road sections with normal traffic, one must be aware that it takes time for changes in road condition to occur. Therefore, it takes time to obtain a basis for model development.

Input in the hypothetical model is essentially the traffic and an expression for the structural strength based on the FWD deflection basin. Traffic that affects the deterioration includes both light vehicles (cars) with studded snow tires, which cause rutting, and heavy vehicles, which cause deformation as well as cracking. The strength is expressed as either calculated tensile strain or the curvature radius of the deflection basin.

At this time a limited amount of data has been analyzed. Good correlation has been achieved between an expression for the cracking (distress points) and tensile strain in the asphalt layer for the cracking model. Furthermore, a first-generation rutting model has been developed.

Future Work

Further improvement of the first generation models will occur based on current monitoring data as well as new data from the continuing data collection. Variation of the timing of the overlay as well as the thickness are other parameters under investigation.

Work is expected to continue for another five years.

In cooperation with the other Nordic countries, a small experiment was established to create a link to SHRP's LTPP. Three sections in the Swedish national experiment that meet the LTPP requirements have been established. Data collection began in the summer of 1992.

Conclusions

International cooperation in the Long-Term Pavement Performance study will greatly benefit the Nordic countries. A lot of effort has gone into such things as financing the research work, site selection, and data collection. The data analysis phase will bring together international expertise to refine our understanding of pavement performance modeling. We do hope that this research will lead to a breakthrough in highway engineering.

Poland

Poland is preparing a detailed program for its long-term investigations on the test sections located on the national road network. The procedures for monitoring pavement test sites will be carefully coordinated with SHRP requirements.

Poland is implementing a pavement management system (PMS) for its main roads (about 30,000 km). In the system we are going to apply the pavement performance models to optimize the maintenance strategies. In this field, we have worked up several tasks to date.

Pavement Inventory

We have inventoried the pavement structures on the national road network. There are about 150 different structures that vary in respect to number of layers, their thicknesses, layer configuration, and the type of material used. We have combined these structures into seven generalized groups according to the criterion for pavement type and for the types of damages and the mechanism of their creation. These generalized groups of structures are illustrated in figure 1.

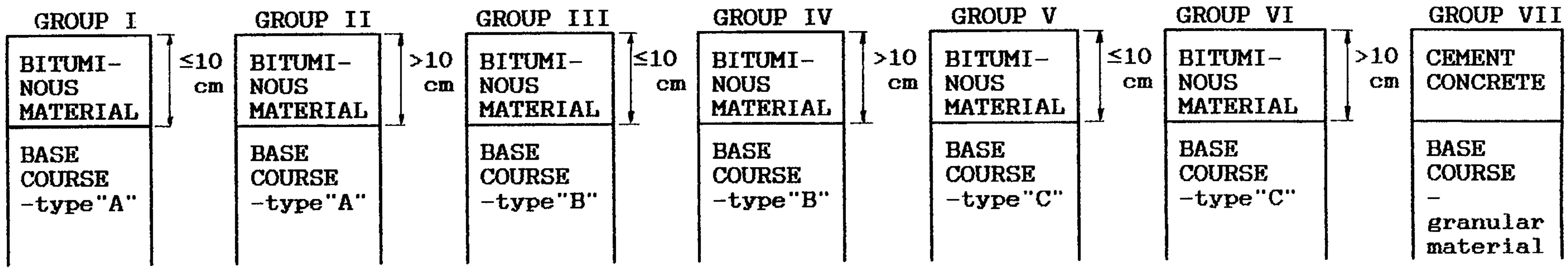
The percentage of these structural groups on the national road network is shown in figure 2. As it can be seen, about 96 percent of roads have pavement structures that meet the requirements of the first four groups. The majority of pavements has a granular base-course.

Performance Model Selection

For the PMS used in Poland we have chosen models that meet the specific requirements of our climatic, traffic and structural conditions. These models describe changes in bearing capacity, cracks, and longitudinal and transverse profile as functions of time or number of load repetitions. For skid resistance we have elaborated our own model. All of them concern generalized groups of structures numbers I to IV only.

Verification

We will verify the performance models on the basis of results from the long-term investigations on test sections. We installed about 100 test sections scattered throughout our country. Their locations are noted in figure 3.



TYPE OF BASE COURSE

A – granular material (broken stone, sand-gravel mix, etc.),
– pavement or sett on the granular layer
B – cement stabilized soil or lean concrete,
– pavement or sett on stabilized layer with thin sub-crust
C – cement concrete

Figure 1. Generalized schemes of pavement structures.

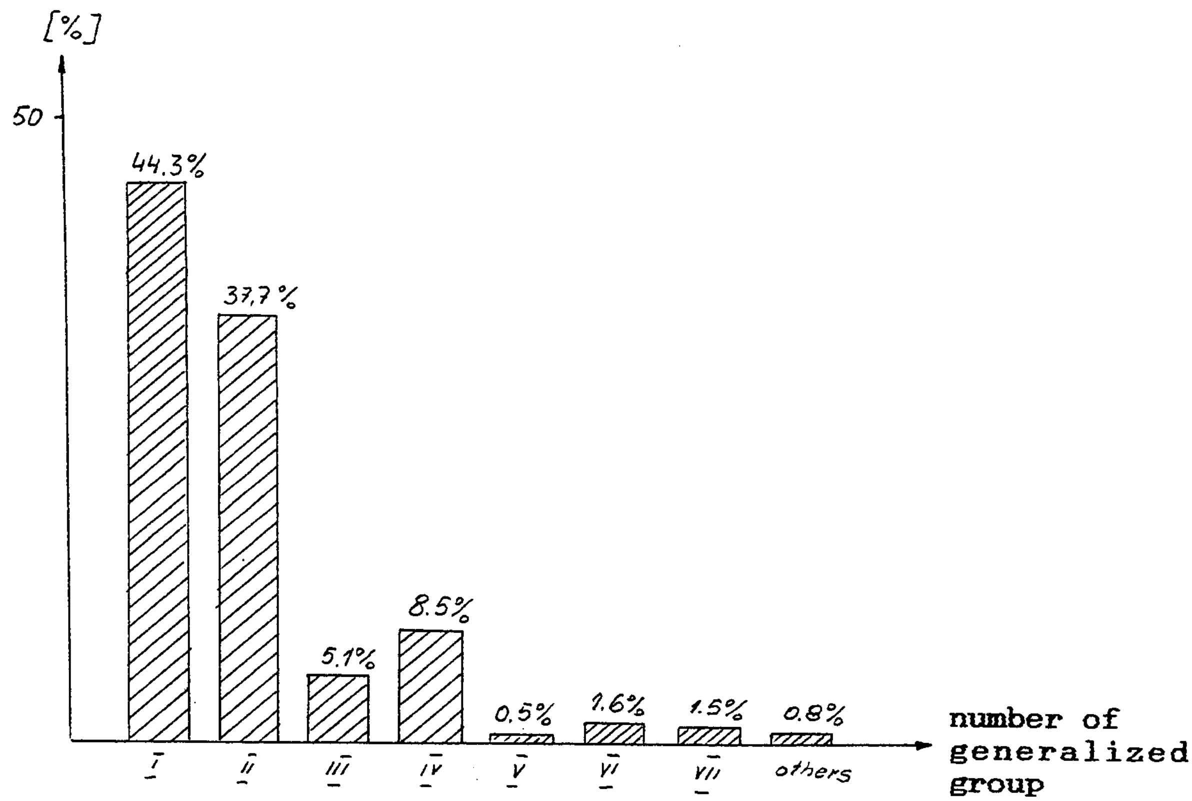


Figure 2. Participation of different generalized structures of pavements on the national road network.

The pavements on the test sites are in good condition. We estimate that for four years at least maintenance will be unnecessary. This year we will perform the inventory inspection (detailed recognition of the properties of subgrades and structural layers) and the first series of periodical testing.

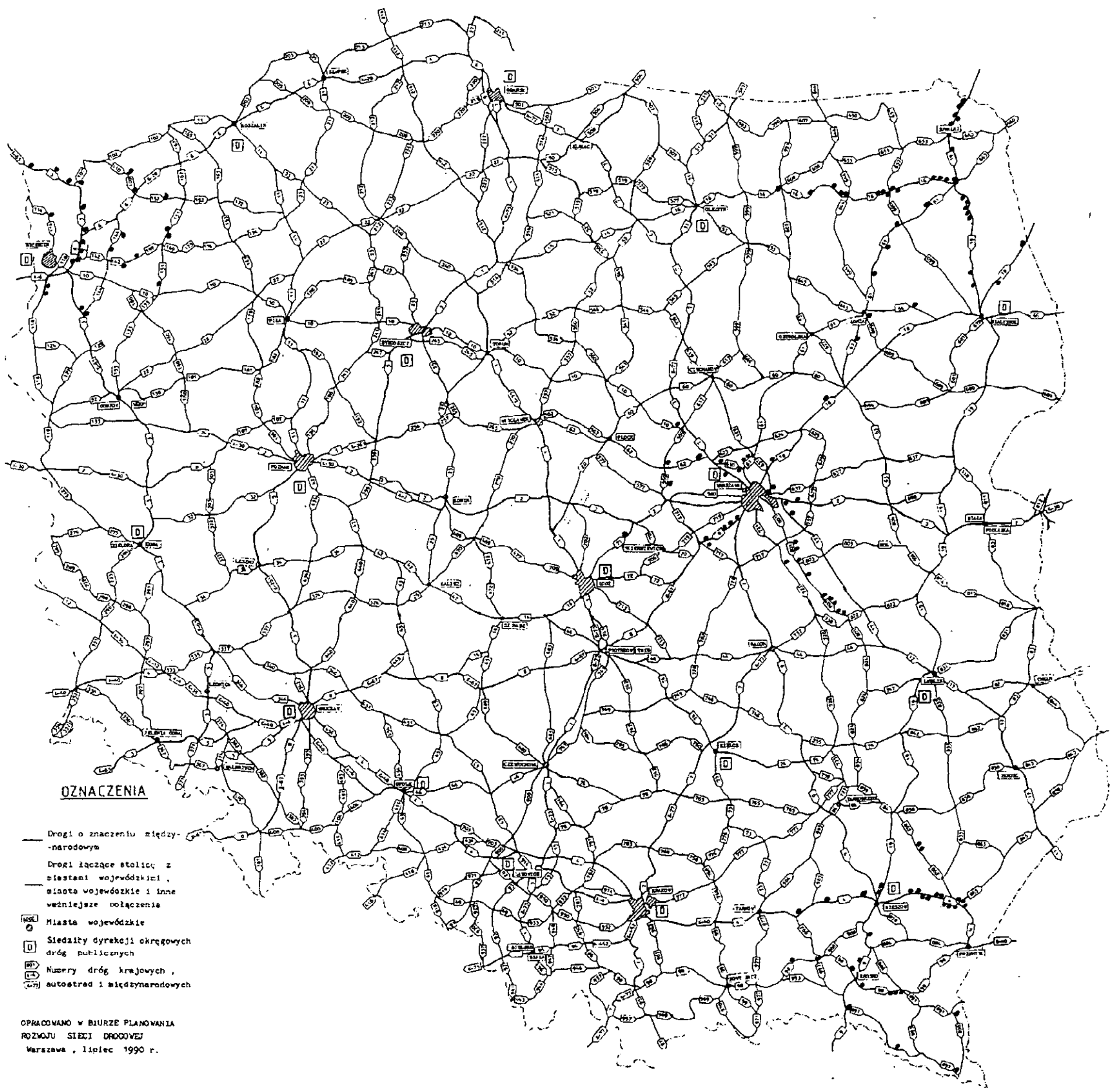
Program Design

The program design for the Polish LTPP study follows.

Inventory inspection

Subgrade

- Properties of soils;
- Subgrade category;
- California Bearing Ratio (CBR), Elasticity moduli (E);
- Moisture content;
- Water table.



· Location of test sites

Figure 3. Locations of test sites on the Polish national road network.

Pavement structural layers:

- Thicknesses of layers and type of material used;
- Properties of granular and stabilized base-courses;
- Compositions of bituminous mixes and asphalt properties.

Pavement surface characteristics:

Historical data on pavement structures and traffic to date.

Climatic conditions (these data will be stored continuously during LTPP program execution):

- Air temperature;
- precipitation;
- frost penetration.

Periodic testing

Average speed of vehicles, types and number of loads (on several sites with Marksman 600 Traffic Counter and Classification System, on the other ones with the portable systems).

Pavement deflections (FWD)

Longitudinal profile (APL)

Transverse profile (apparatus constructed in the Roads and Bridges Research Institute, RBRI, in Warsaw).

Skid resistance (apparatus constructed in the RBRI)

Visual inspection

Periodical tests will be carried out once a year.

After finishing inventory inspection and the first series of the periodical tests, we will prepare the comparative analysis of methods and procedures recommended by SHRP and those used in our program.

New freeways are planned to be constructed in Poland so there will be a possibility to create new test sites with heavy traffic in 1993 or 1994. On these sites all changes of structural and functional conditions of pavements will be observed. On some of these sites the installation of gauges to measure temperature, moisture, stress/strain and deflection distribution in the different structural layers and in the subgrade is under consideration.

Slovenia

Road organizations

The National Road Administration of Slovenia, which is part of the Ministry for Transportation and Communications, has the responsibility for highways, arterial and regional roads.

Routine maintenance activities are performed by authorized regional road agencies. Contracts for rehabilitation, reconstruction, and new construction are offered to national and international bidders on the basis of a competitive tendering system. Usually the lowest bidder is awarded the contract. In general, international tenders are called when the work is co-financed by European and international financial associations.

The National Road Administration also ensures that road making practices are maintained at the highest possible level. Research is done by independent institutions, and work is focused on finding solutions to Slovenian problems, including the transfer of technology from other nations. The greater part of road research in Slovenia is guided by the "Družba za raziskave v prometni in cestni stroki Slovenije" or Road and Transportation Research Association of Slovenia.

Current research issues include those pertaining to earth works (construction of roads and highways on low bearing ground), use of waste materials (recycling) and asphalt pavements (modified asphalt binders, procedures assuring environmental protection).

Slovenia is implementing a road management system to help manage its network. The World Bank's HDM model has been selected, together with all related and necessary activities. This is already shaping the planning for future work.

Activities leading to Slovenia's active participation with SHRP

Slovenia's first contact with SHRP was through the information that was made available while participating at various international conferences and/or congresses in the years 1990-1991:

- Congress on Road Bearing Capacity in Trondheim, Norway, 1990
- International OECD Conference on FORCE Project in La Baule, France, 1991
- International Road Federation Conference in Belgrade, Yugoslavia, 1991
- International SHRP Conference in Gothenburg, Sweden, 1991

- PIARC Road Congress in Marrakech, Morocco, 1991.

The importance of the SHRP program was evident:

- it addressed the problems of road deterioration caused by traffic volume/load and climatic conditions,
- it focused on the development of pragmatic products for immediate use (in maintenance and other technical areas),
- it aimed to produce improved pavement design procedures that would meet specific conditions through the LTPP program, and
- it placed high priority on international coordination and cooperation.

After learning about the different levels of participation for overseas countries in the Long-Term Pavement Performance program (presented at the 1989 conference in Gothenburg), Slovenia initiated the necessary steps to sponsor a program that would maximize her benefits of SHRP research. A participating project, together with active participation would:

- be a means to obtain up-to-date SHRP technical information,
- guarantee the availability of SHRP-related outputs,
- necessitate the identification of differences and thus result in timely calibration to Slovenia's conditions,
- enhance technical knowledge and trigger further research,
- promote international participation.

Slovenia first contacted SHRP in March, 1991. From that moment onwards, Slovenia had intensive correspondence with SHRP staff. Slovenia was included in the SHRP mailing list in June, 1991. Shortly afterwards, the National Road Administration of Slovenia designated its national SHRP coordinator and a LTPP Working Group was formed. By October 1991, the working group was already gathering information for the SHRP-LTPP general pavement studies test sites, making sure that all of the requirements of SHRP guidelines were met. Work on Slovenia's GPS Candidate Project was supported and sponsored by the Ministry for Science and Technology as well as the Ministry for Traffic and Communications.

Slovenia became actively involved in the SHRP and LTPP programs when it sent, in July 1992, a loaned staff officer for a year. Slovenia has already benefitted from SHRP's publications, it has been officially accepted to the international community of participants in the LTPP study, but the close links through its loaned staff officer will contribute to a much better understanding of existing problems and their solution. Through the national coordinator in Slovenia, information on SHRP research is disseminated not only to the LTPP working group, but to research institutes, universities, and other users where implementation of SHRP products may prove beneficial. Of particular interest are those of pavement design and performance, and characterizing the behavior of pavement materials.

SHRP-LTPP-Slovenia Project

The LTPP working group identified seven test sites for the project at different locations in Slovenia (see table 1). Since they were all asphalt pavements that were planned for overlay, the General Pavement Study "GPS-6B: AC Overlay of AC Pavement" was selected. The study is representative of the rehabilitation work that is being conducted on Slovenia's pavements (alongside with reconstruction work). There are therefore seven experiments, six of which consist of two adjacent sections (the seventh having only one section). On each of the adjacent test sections, different design strategies will be selected by choosing different but appropriate (with respect to traffic volume and traffic load) overlay thicknesses. On each test section, the overlay thickness will correspond to a ten-year life expectancy before any significant deterioration due to traffic or the oxidation of the asphalt binder is expected to appear. On each adjacent test section, a five-year life expectancy design will be selected. This should provide additional information on road deterioration based on the comparison of data from the long-term pavement monitoring.

Table 1. Selected Sites For GPS-6: AC Overlay of AC Pavement

Exp. No.	Road No.	Sect. No.	Location	Chainage (km)		No. of Sect.	No. of Lanes	Road Width (m)	Year of Construction	Year of 1st Overlay
				From	To					
1	M 1	221	Trebnje—Karteljevo	3.30	3.50	1	2	2 × 4.2	1973	—
2	M10-3	332	Radeče—Boštanj	5.75	6.10	2	2	2 × 3.0	1965	—
3	M 3-3	1290	Sl. Bistrica—Hajdina	9.50	9.82	2	2	2 × 3.1	1967	—
4	R 351	1302	Bratonci—Dokležovje	2.55	2.90	2	2	2 × 3.1	1964	—
5	R 353	1311	Pavlovci—Ormož	0.20	0.55	2	2	2 × 3.2	1965	1979
6	R 362	1333	Podsreda—Brestanica	12.98	13.29	2	2	2 × 2.5	1968	—
7	R 340	1248	Mozirje—Radmirje	8.91	9.21	2	2	2 × 3.0	1964	1975

All experiments fall into the Wet-Freeze environmental zone, which prevails in Slovenia. According to the sampling factorial of the Recruitment Guidelines for Additional GPS Candidate Projects, they have the following cell identification numbers:

Cell ID No.	Number of Experiments	Number of Sections
2	1	2
5	1	2
9	1	2
13	3	2
15	1	1

Considering the necessity to meet the requirements of SHRP-LTPP guidelines, the selected test sections could be considered as being representative of Slovenia's road network.

LTPP Data Collection Activities

Most of the inventory data for the LTPP program were collected during the preverification stage (see table 2), when the candidate project was being prepared for SHRP nomination. Based on visual inspection and deflection data analysis (data obtained with Lacroix Deflectograph), five of the test sites were later slightly repositioned for purposes of obtaining better section homogeneity.

Since then, measurements of longitudinal and transverse profile have been performed on all of the test sites. The ARAN multifunctional vehicle was used for these data gathering purposes. Records of surface distress have been obtained as well. Falling weight deflectometer measurements will be conducted in 1993, before and after the placement of overlays. Traffic information (traffic volume) is available from the road data base of the National Road Administration. For the purposes of gathering the remaining traffic data (pertaining to traffic load and vehicle classification), options for purchasing weigh-in-motion equipment are being investigated. The meteorological center will provide the necessary weather parameters through its existing local weather stations.

Material testing is performed according to the SHRP guidelines. For field testing and sampling purposes, two test pits were made per site. Asphalt cores and unbound material samples have been taken from all locations. Laboratory testing of bound and unbound materials is underway. Properties of the aggregate, asphalt cement, and asphalt mixture as a whole are being investigated. Other completed activities include:

- determining layer thicknesses of the pavement structure
- material classification
- plate loading tests according to German standards BAST-E1 (January 1968) and BAST-C4 (April 1969)
- density measurements and moisture content (using nuclear isotopes)
- determining CBR value of subbase layer according to Swiss standard SNV 70 312

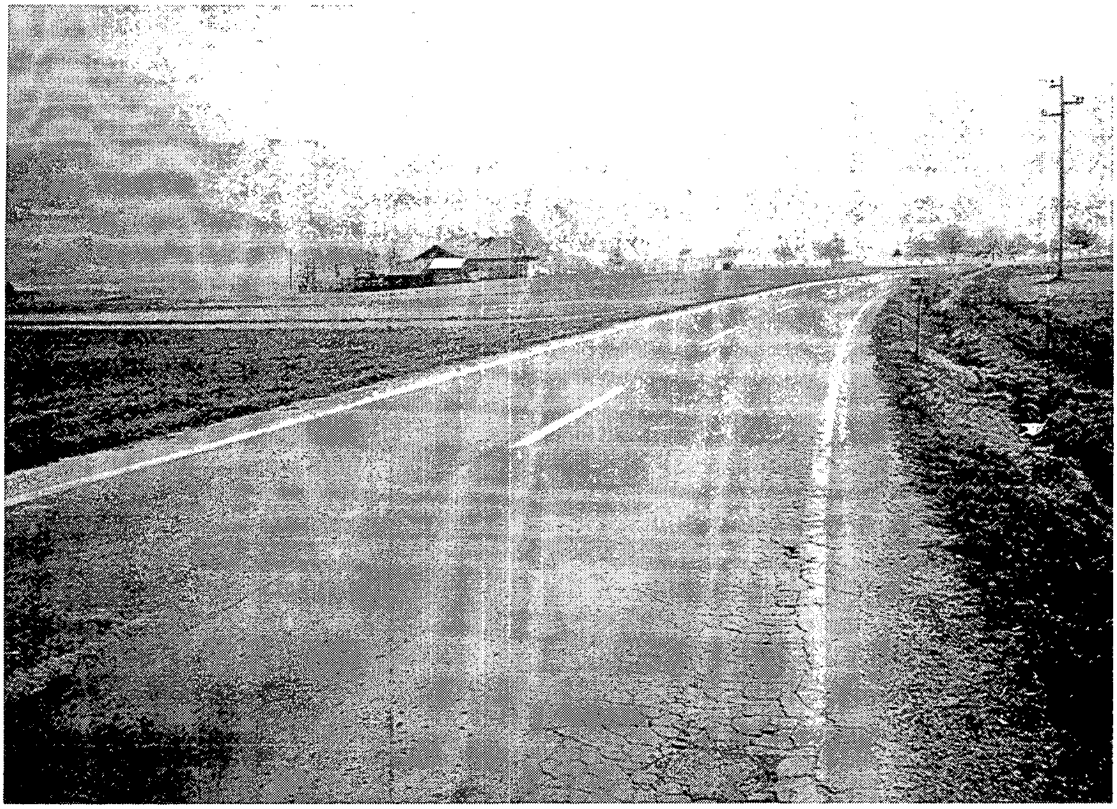
A decision will soon be made for setting up an information management system for purposes of storing data, transferring data to the TRB IMS, as well as analyzing the data.

Table 2. Traffic and layer description data

Exp. No.	Road No.	Traffic Data: Year of Count	AADT	Trucks (%)	ESAL	Layer Description Data: Layer No.	Layer Description	Layer Thickness (in.)	Material Type Classification[1]
1	M 1	1990	11,955	21	360,620	1	original surface	1.6	dense-graded HMAC
						2	base	3.9	bit. bound base, dense-graded, hot-laid, CPM
						3	subbase	17.0	uncrushed gravel
						4	subgrade		sandy clay
2	M10-3	1988	3,983	26	140,346	1	original surface	1.2	dense-graded HMAC
						2	base	2.0	bit. bound base, dense-graded, hot-laid, CPM
						3	subbase	15.7	uncrushed gravel
						4	subgrade		sandy clay
3	M 3-3	1990	3,075	28	120,946	1	original surface	1.2	dense-graded HMAC
						2	base	2.0	bit. bound base, dense-graded, hot-laid, CPM
						3	subbase	22.4	crushed stone
						4	subgrade		sandy clay
4	R 351	1989	2,057	20	54,925	1	original surface	3.9	bit. bound base, dense-graded, hot-laid, CPM
						2	subbase	11.8	uncrushed gravel
						3	subgrade		sandy clay
5	R 353	1989	1,930	23	65,328	1	original surface	3.0	dense-graded HMAC
						2	base	2.0	bit. bound base, dense-graded, hot-laid, CMP
						3	subbase	15.7	crushed stone
						4	fill	61.0	sandy clay
						5	subgrade		sandy clay
6	R 362	1990	3,868	13	67,686	1	original surface	2.4	bit. bound base, dense-graded, hot-laid, CPM
						2	subbase	19.7	uncrushed gravel
						3	subgrade		sandy clay
7	R 340	1989	2,936	11	44,661	1	original surface	1.2	dense-graded HMAC
						2	base	2.0	bit. bound base, dense-graded, hot-laid, CPM
						3	subbase	11.8	uncrushed gravel
						4	subgrade		clayey gravel

[1]SHRP codes

Experiment No.: 2, Route No.: M10-3, Section No.: 332



Experiment No.: 3, Route No.: M3-3, Section No.: 1290

Experiment No.: 5, Route No.: R 353, Section No.: 1311

Experiment No.: 7, Route No.: R340, Section No.: 1248

Switzerland

The Swiss Normalization Committee is about to establish a new standard for polymer bitumen. It appeared that there existed only a few comparing considerations, and thus arose the need to test different polymer binders under comparable conditions.

In this period, highway construction in the canton Wallis between Riddes and Sion on a stretch of about 15 km was accelerated. The respective authorities of the canton Wallis proposed to the Swiss Federal Highways Office the construction of a stretch of comparison of 50,000 m^2 as a whole.

The length of this stretch was chosen in a way that on each section a whole truck of polymer bitumen could be worked up. Out of this consideration came sixteen sections of 3,000 m^2 each. To judge the influence of the binding agents, the sections were placed under comparative conditions (underlay, weather conditions, equipment) while the mixture was being worked up in the same asphalt plant, using the same mineral products and according to the same prescription. Also, the thickness of the layer of the AB 16 S was held unchanged.

The question of choosing the right binders for this research project was extremely delicate. On the one hand, as many products as possible, showing different modifications, should be applied. On the other hand, new products without sufficient experience on construction sites should be excluded. The requirements regarding the polymer-modified binders were fixed as follows:

- Binders of additives which have been used successfully for at least three years in Switzerland or abroad under similar conditions.

The comparative sections had been realized in the summer of 1988 under good placement conditions. The producers of binding agents were all invited to survey and comment the working-up and placement of the mixture. From the written comments, it could be concluded that the sections had been placed in due order also from the binder producers' point of view. Each of the sixteen sections was worked up, placed and compacted according to the standards and with consideration of the general rules of civil engineering.

As the test sections were placed, the placement conditions were registered and recorded and samples of the binders and mixtures were taken. After placement, about 500 cores were drilled. The extensive test program task was distributed among ten laboratories.

The first report represents an inventory at time zero. After two, four, and eight years, further samples will be taken and more investigations made. A final result of the tests will hence be possible within a few years. Conclusions with respect to products cannot be drawn at this time. However, valuable comparisons could be made in the course of the test program.

An essential target was to find a basis for the elaboration of a Swiss pre-standard for polymer-modified bitumen. Although final comparative considerations for lack of a long-term experience are not possible yet, it may be said that the primary aim has been achieved.

Binder Selection

An overview of the chosen binding agents is presented below and in table 1.

- Ready-to-use polymer-modified binder: Nr. 3, 4, 5, 6, 7, 8, 9, 11, 14
- Synthetic additives which are being added to the mineral products and the bitumen in the mixer of the asphalt plant: Nr. 10, 12
- PmB, which had been mixed in a moveable mixing plant on the test site shortly before its application: Nr. 7.

Table 1. Selected binders

Number	Binder	Polymer type	Additive	Polymer content
1	B 80/100 semiblown	—	—	—
2	B 60/70	—	—	—
3	B 80/100 + oils	SBS	—	3%
4	B 40/50 + oils	SBS	—	3%
5	B 80/100 + oils	SBS	—	5%
6	B 40/50 + oils	SBS	—	5%
7	—	Polyethylene/ polypropylene	—	6%
8	—	Isobutylene + EVA	—	11.5%
9	B 60/70 + oxidation agents	EPDM	—	4%
10	B 80/100 semiblown	—	Polyolefin	7%
11	B 80/100	SBS	—	4%
12	B 80/100 semiblown	—	SBS + EVA + agent	—
13	B 80/100	—	Lake Asphalt	3.6%
14	—		—	5%
15	B 80/100 direct distillation	—	—	—
16	B 60/70	—	—	—

Sections without synthetic additives also were used:

Nr. 1 and 2:	Bitumen that, by blowing in the refinery, was brought up to a certain penetration grade. The so-called semiblown bitumen should not be confounded with the oxidized bitumen. Such bitumen is applied only industrially.
Nr. 13:	Bitumen B 80/100 with Trinidad Lake Asphalt
Nr. 15 and 16:	Bitumen with a penetration grade that is fixed in the course of the distillation process. So-called direct-distilled bitumen needs no further regulation of the bitumen hardness by blowing.

Test Program

Concept

The test program should provide for long-term observation of the sixteen test sections and for elaboration of a pre-standard for polymer bitumen.

The first report contains only the tests and measurements made at the moment of placement. Further tests are planned after 2, 4, and 8 years.

A very extensive test program with the assistance of ten laboratories was developed in order to include as many parameters as possible. In addition to the actual laboratory experiments, in situ measurements before and after the placement were made. The preparation and placement conditions were recorded with great precision, and a measuring station to continually register the meteorological conditions and the traffic density was installed.

Preliminary tests

aggregate:	all tests which are in the quality prescriptions (Swiss standard)
binders:	penetration and softening point R + B
mixtures:	mixture control, Marshall, sieve curve
subbase:	falling-weight deflectometer

Tests on binders

Density

1 Binder in status of delivery (BD)
2 Binder recovered from the bituminous mixture (BR)

Penetration

3	BD	5, 15, 25, 35°C
4	BD	25°C; second laboratory
5	BR	5, 15, 25, 35°C
6	Binder after aging (BA), rolling thin film oven test (RTFOT)	25°C
7	BA, rotating flask (DIN)	25°C

Softening point R and B

8	BD	
9	BD	2. second laboratory
10	BR	
11	BA (RTFOT)	
12	BA (DIN)	

Fraass brittleness

13 BD
14 BR
15 BA (RTFOT)
16 BA (DIN)

Ductility

17	BD	4, 7, 25°C
18	BR	7°C
19	BA (RTFOT)	7°C

Elastic Recovery (DIN)

20	BD	7, 25°C
21	BR	25°C
22	BA (RTFOT)	7, 25°C

Dynamic viscosity: 60, 90, 130, 150, 170°C

23 BD
24 BR
25 BA (RTFOT)

26 Elastic rebound (STIA)

27 Shear modulus

Water immersion test (water sensitivity)

28	BD	standard aggregate
29	BD	used aggregate

30 Storage stability

Direct strain

31	BD	-10, 20°C
32	BR	-10, 20°C
33	BA (RTFOT)	-10, 20°C
34	BA (DIN)	-10, 20°C

Axial shear bending test

35 BR

36 Chromatography on permeable gel

37 Fluorescent microscopy

38 IR-spectroscopy

Tests on Bituminous Mixtures

101 Binder content, sieve curve

102 Density, apparent density

103 Marshall

104 Gyratory (LCPC)

Indirect tensile test
105 on cores drilled from laboratory-compacted plate
106 on cores drilled from the test section

107 Complex modulus

108 Fatigue test

109 Axial shear bending test

110 Traffic simulator (LCPC)

111 Static creep test

112 Dynamic creep test

Pulsator
113 Dynamic compression test
114 Dynamic flexion test

115 Deep temperature relaxation test
116 Deep temperature contraction test

Measurements in situ at time zero

- density measured by nuclear gauge
- falling-weight deflectometer
- skid resistance SRT and drainability
- dynamic skid resistance by skidometer
- geometric properties of the surface by ARAN
    - ♦ Transversal and longitudinal gradient
    - ♦ depth of ruts
    - ♦ index of driving comfort
- index of driving comfort (SAR)
- visual judgement of the degradations
- video film from the surface and the environment (ARAN)

Permanent measurements in situ

- traffic
- temperature at the surface of the road and between each asphalt layer
- measurement of the electric conductivity of the running water
- air temperature and humidity
- sunshine
- snow and ice

Reports

A first brief report was published at the Eurobitume Congress, Madrid 1989. A second brief report will be published at the next Eurobitume Congress, to be held in Copenhagen in 1993. Several other reports will be published during the long-term performance testing. The final report is scheduled for 1998.

United Kingdom

In the United Kingdom, more than 500 bituminous road test sections and about 250 concrete sections have been constructed in the last thirty years. Present pavement design methodologies are based on the performance of these test sections. The techniques used in the Strategic Highway Research Program are different from the techniques used to monitor these sections, so these historical studies are not directly usable in LTPP.

An agreement was made at the 1989 SHRP conference in Gothenburg that the European LTPP pilot trials would be carried out to complement and extend the General Pavement Studies and Specific Pavement Studies experiments in the United States and Canada. These trials would help to address the questions about differences in materials, units of measure, performance monitoring and data storage and transfer.

Test sections of bituminous overlays on heavily trafficked, jointed concrete roads are being constructed in the United Kingdom to comply with the requirements of the SHRP GPS-7B and SPS-6 experiments. The objective of the United Kingdom trials is to develop a design procedure for overlays on jointed concrete roads.

Design of Road Trials

The test sections are designed to study the performance under heavy traffic of different thicknesses of hot-rolled asphalt overlay on jointed reinforced and unreinforced concrete pavements. In addition to the general program, the crack and seat and sawcut and seal techniques are being evaluated. The potential benefits of geotextiles, geogrids, and stress-absorbing membrane interlayers (SAMIs) also are under assessment.

The proposed design of the United Kingdom SPS-6 experiment is shown in the extended SHRP matrix in table 1. The United Kingdom is located in the wet/no freeze climatological zone. The standard SHRP matrix has been extended in this area to include additional test sections. Table 2 shows the design of the GPS-7B experiment.

Construction of Trials

Construction of the trials, all of which form part of major rehabilitation schemes, began in 1990. To date, three trials have been constructed and another is planned.

Table 1. United Kingdom SPS-6 test sections

Climate		Wet/Freeze				Wet/No Freeze				Dry/Freeze			
Pavement Type		JPCP		JRCP		JPCP		JRCP		JPCP		JRCP	
Initial condition		F	P	F	P	F	P	F	P	F	P	F	P
Maintenance	Overlay (in.)												
Routine maintenance	0												
Minimum restoration	0												
	4												
	4*												
Maximum restoration	0												
	4												
Crack/break and seat	4												
	8												
Crack/break and seat	6												
Minimum restoration	8												
	8*												
Maximum restoration	4*												
	8												
	8*												

*Saw and seal overlay above joints; F = Fair condition; P = Poor condition

Table 2. United Kingdom GPS-7B test sections

Climate	Wet/No Freeze			
Subgrade Type	Fine			
Traffic Rate	High			
Pavement Type	JPCP		JRCP	
Initial Condition	Fair	Poor	Fair	Poor
Overlay Thickness (in.)				
3				
4				
6				
8				

Trial on M2 Motorway

The trial on the London-bound carriageway of the M2 Motorway that links Dover with London was constructed in May 1990. The motorway has two lanes and a hard shoulder in each direction. In three test sections, a needlepunched geotextile was bonded to the concrete with bitumen before overlaying. In four test sections, ethylene vinyl acetate-modified binder was incorporated in the hot-rolled asphalt. The condition of the original concrete running surface was generally poor, particularly at the joints. Extensive spalling had occurred at some joints. At others, temporary repairs had been performed. Consequently, over half of the joints were renewed before overlay. Information about the design of the trial and the overlays is presented in table 3.

Table 3. Design and construction of trial on M2 motorway

Section Number	Geotextile	Overlay Material	Overlay Thickness
1	Yes	Hot-rolled asphalt with EVA	75 mm
2	Yes	Hot-rolled asphalt with EVA	100 mm
3	No	Hot-rolled asphalt with EVA	100 mm
4	No	Hot-rolled asphalt	100 mm
5	No	Hot-rolled asphalt	200 mm
6	Yes	Hot-rolled asphalt with EVA	140 mm
Original Construction			
	Subbase	200-mm flint gravel	
	Concrete	250-mm jointed reinforced	
	Spacing of joints	24 m (80 ft.)	
	Year opened to traffic	1963	
	Cumulative traffic in lane 1	32 million ESALs	
Bituminous overlay			
	Date overlaid	May 1990	
	Length of trial sections	150 m (492 ft.)	
	Annual traffic in lane 1	2.2 million ESALs	

Trial on A45 Trunk Road

The second trial was constructed in October 1990 on the A45 trunk road at Bury St. Edmunds bypass in Suffolk, in the east of England. This is an urban dual carriageway with two traffic lanes in each direction. The concrete was generally in fair condition and very few

repairs were performed before overlay. The thickness of overlay was limited by drainage considerations in the urban area. It was decided to incorporate styrene butadiene styrene (SBS) additive in the hot-rolled asphalt overlay for the main works. The sawcut and seal technique is a feature of this trial. Details of the overlay applied are given in table 4.

Table 4. Design and construction of trial on A45 trunk road

Section Number	Overlay Material	Overlay Thickness	Sawcut and seal
1	Hot-rolled asphalt	100 mm	Yes
2	Hot-rolled asphalt	100 mm	No
3	Hot-rolled asphalt with SBS	100 mm	No
Original Construction			
	Subbase	200-mm cement-bound granular material	
	Concrete	250-mm jointed plain	
	Spacing of joints	5 m (16 ft.)	
	Year opened to traffic	1974	
	Cumulative traffic in lane 1	23 million ESALs	
Bituminous Overlay			
	Date overlaid	October 1990	
	Length of trial sections	150 m (492 ft.)	
	Annual traffic in lane 1	2 million ESALs	

Trial on M5 Motorway

This trial was constructed in May 1992 on the northbound carriageway of the M5 Motorway near Taunton in Somerset. The motorway has three lanes and a hard shoulder in each direction. The existing concrete running surface was generally in poor condition, particularly in lane 1 adjacent to the hard shoulder where several concrete slabs had been replaced with bituminous material as part of an ongoing maintenance program. After treatment, all the test sections were overlaid with hot-rolled asphalt basecourse and wearing course material. The trial incorporated sections in which a Wirtgen guillotine was used to crack the concrete at various spacings as part of the crack-and-seat technique (figure 1). Other sections incorporated SAMIs, grids, and sawcut and seal. The total length of the site is 2 km (1.25 miles). Detailed design information about the site and overlay thicknesses is given in table 5.

Future Trials

A further SPS-6 trial is planned for a dual carriageway trunk road. Test sections will include the crack-and-seat treatment with the cracking operation performed with different types of available equipment.

Figure 1. Wirtgen guillotine used to crack concrete pavement in crack and seat operation.

Measurements Before Construction

Surface Condition

A detailed manual visual survey was performed at each site to record general condition and specific defects within the concrete slabs and at the joints (figure 2). In conjunction with other measurements, these surveys were used to select the precise location of the test sections.

Slab Movement

It is most important to establish the condition of the joints before overlaying in respect to their ability to accommodate thermal movements and to transfer the traffic loads between slabs. If adjacent concrete slabs are not free to slide on the load transfer bars, then high stresses may be generated within the slabs due to seasonal changes in temperature. This

Table 5. Design and construction of trial on M5 motorway

Section Number	Treatment	Overlay Thickness
1	Crack and seat 0.5 m spacing	100 mm
2	Crack and seat 1.0 m spacing	100 mm
3	Crack and seat 2.0 m spacing	100 mm
4	Control (no treatment)	100 mm
5	Crack and seat 0.5 m spacing	150 mm
6	Crack and seat 1.0 m spacing	150 mm
7	Crack and seat 2.0 m spacing	150 mm
8	Control (no treatment)	150 mm
9	Sawcut and seal	100 mm
10	Sawcut and seal	150 mm
11	Fiberscreed SAMI joint treatment	150 mm
12	Glasgrid joint treatment	150 mm
Originial Construction	Subbase	225-mm Type 1 subbase
	Concrete	230-mm jointed plain
	Spacing of joints	6 m (20 ft.)
	Date opened to traffic	April 1974
	Cumulative traffic in lane 1	22 million ESALs
Bituminous Overlay	Date overlaid	May 1992
	Length of trial sections	150 m (492 ft.)
	Annual traffic in lane 1	1.5 million ESALs

Figure 2. Visual survey team

Figure 3. Measuring horizontal joint movement using DEMEC gauge.

might result in mid-slab cracking and spalling at the joints or increase the thermal movements at the joints that are free. Large movements at individual joints increases the potential for reflection cracking in the new overlay above those joints.

In the United Kingdom, thermal movements at joints are determined with reference to pairs of metal studs that are inserted in the surface of the concrete approximately 200 mm apart to span a joint or crack (figure 3). These studs act as the datum for the measurements. The distance between them is measured at different times during the year when the concrete is at different temperatures. When the measurements are taken it is important to ensure that the temperature within the concrete is constant with depth to avoid thermal warping.

Deflections

Before the trials were constructed, deflections were measured with a Dynatest 8000 falling-weight deflectometer (figure 4). The measurements were made during cold weather when the concrete had contracted and the joints and cracks were relatively wide. This represented the most severe situation for load transfer. On the M2 motorway the deflections were measured in the outer wheelpath of lane 1 with the loading plate of the falling-weight deflectometer positioned first on one side of the joint, then on the other, and finally at the geometric center of the slabs. The tests all were performed in accordance with the SHRP-LTPP manual for falling-weight deflectometer testing using the three loads recommended (SHRP, 1989).

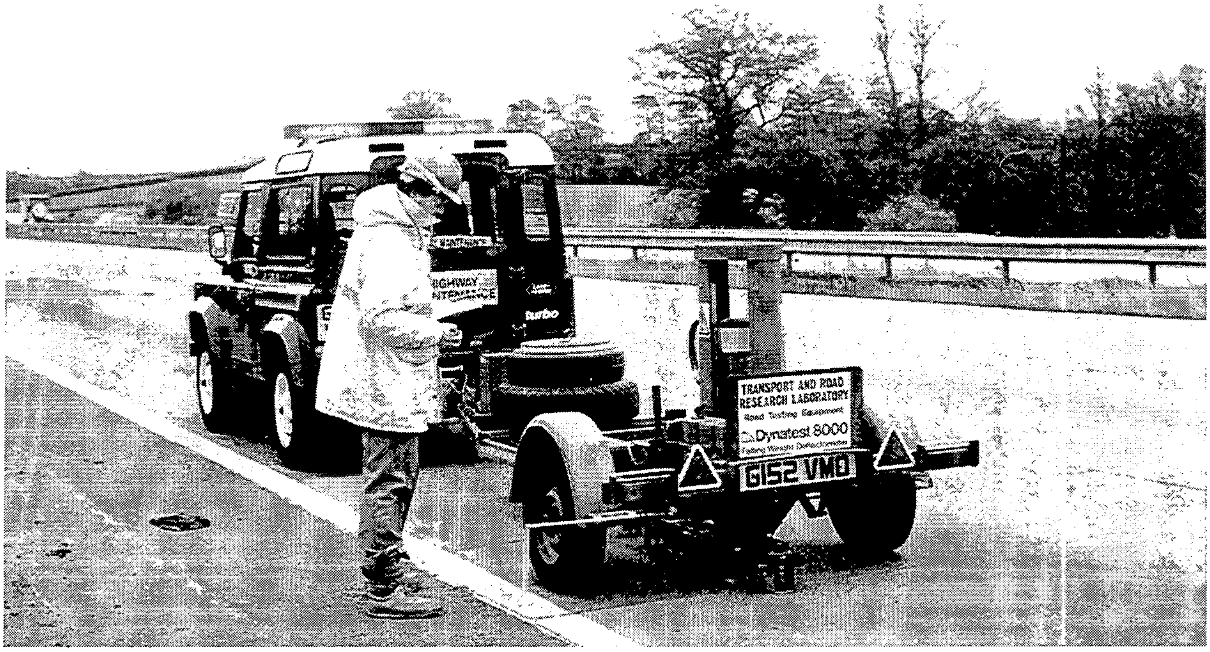


Figure 4. Dynatest falling-weight deflectometer.

Analysis of these measurements showed that the deflections were not influenced by the load or by which side of the join the plate was positioned. Consequently, to reduce testing time substantially, subsequent measurements have been performed using a 770 kPa load, generally applied to only one side of the joint and in the center of the slab.

For the trial on the M5 motorway, deflections at the joints and in the mid-slab positions also were measured with a special deflectograph equipped with a double measuring beam (figure 5). The position of the measuring frame on the road is controlled independently so that the two beam tips are positioned either side of a joint or crack. The deflection at these two locations is measured as the loading wheels traverse the joints. A preliminary analysis indicates good correlation with the falling-weight deflectometer measurements.

Longitudinal Profile

The longitudinal profile and the surface texture of the concrete was measured using the TRL High-speed Road Monitor, shown in figure 6 and described by Cooper (1985). Specific defects including slab misalignment caused by subsidence, slab cracking and stepping at joints can be identified by these measurements.

Traffic

All sites selected for LTPP studies in the United Kingdom are heavily trafficked by cars and commercial vehicles. The general method of assessing traffic loading on the United Kingdom motorway and trunk road network is to perform regular classified traffic counts at 3,000 sites on a rotating basis, each site to be surveyed every five years. Continuous counts and

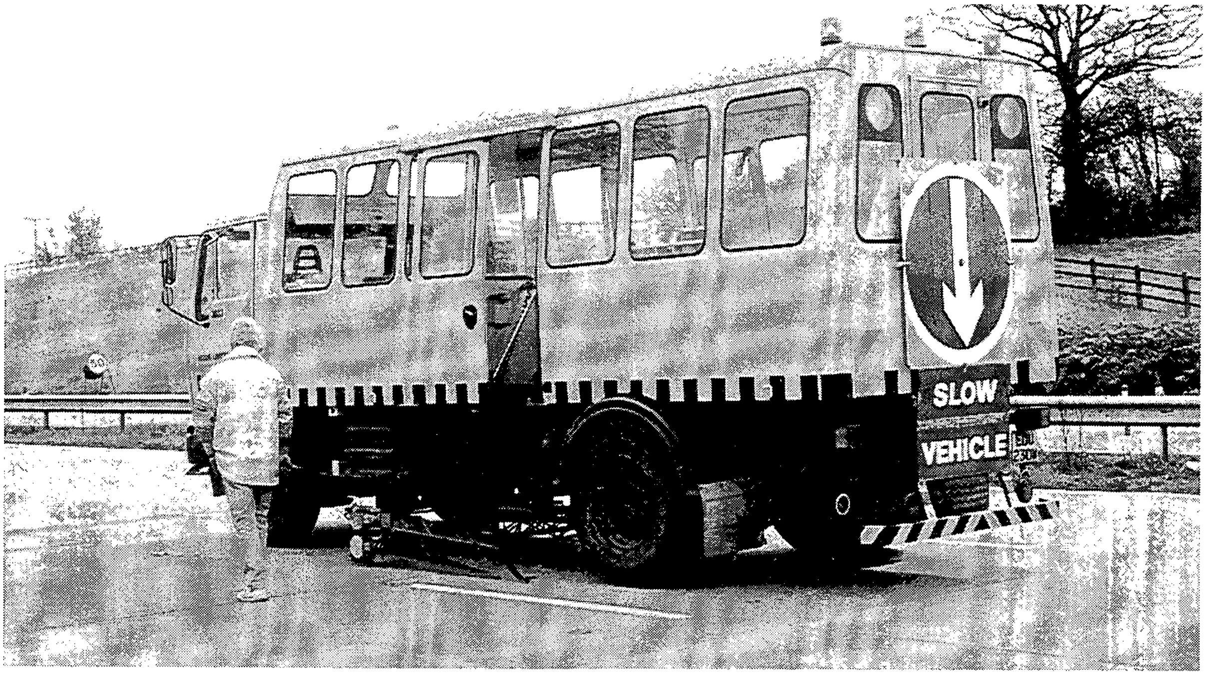


Figure 5. Special deflectograph with double beam to assess load transfer at joints.

Figure 6. High Speed Survey Vehicle that measures longitudinal profile, surface texture, rutting, gradient and videorecords visual condition.

weighscale measurements also are performed at strategic sites. From these observations, procedures were developed by Robinson (1988) to predict the traffic loading at specific sites from comprehensive classified traffic counts conducted at those sites.

Materials Testing

During construction of the trials, samples of hot bituminous materials were taken from the hopper of the paving machine and tested for compliance with specification in terms of aggregate grading and binder content. Temperatures of the hot bituminous mixes were monitored on site in and behind the paver to ensure that laying and compaction were done to specification.

Sampling

The bituminous materials and the concrete were sampled by coring to determine thickness of the layers and to carry out performance-related laboratory tests. Cores 150 mm in diameter were taken from between the wheel tracks of lane 1 at intervals along the test sections in order to obtain a measure of any variability which might have occurred within the trial lengths. This procedure differs from that recommended by SHRP in which samples are taken from one end of the test section only. The SHRP procedure therefore does not permit an assessment of possible variability in the construction materials.

It was not possible to obtain samples from the granular subbases or from the underlying subgrades. However, some information on the type and thickness of the materials is available from records of the original construction.

Bulk samples of aggregate, bitumen, and the mixtures have been taken and stored according to SHRP requirements for use in the asphalt and asphalt mixture testing program in the United States.

Laboratory Tests

The tests that are being carried out on the cores are listed in table 6.

Performance Monitoring

The in-service performance of the road trials is assessed by measuring the condition of the test sections in the spring and fall. Friction, measured in terms of the Sideway Force Coefficient using the Sideway-force Routine Investigation Machine (SCRIM) is expressed as a mean value measured during the summer as described by Rogers and Gargett (1991).

The long-term condition measurements that will be performed are as follows:

- visual condition of the road surface;

Table 6. United Kingdom laboratory tests of materials.

Tests on Concrete	Tests on Asphalt
1. Core examination and thickness	1. Core examination and thickness (BS598 (1987))
2. Compressive strength (BS 1881 Part 120 (1983))	2. Bulk and maximum specific gravity (BS598 (1987))
3. Splitting tensile strength (BS 1881 Part 117 (1983))	3. Elastic stiffness(BS DD213 (1993))
4. Static modulus of elasticity (BS 1881 Part 121 (1983))	4. Creep stiffness (BS DD 185 (1990))
	5. Wheel-tracking rate (BS DD184 (1990))
	6. Type and classification of coarse and fine aggregate (BS 812 (1975))
	7. Bitumen content (BS 598 (1987))
	8. Penetration of bitumen at 55°, 77°, and 275°F
	9. Viscosity of bitumen at 77°, 140°, and 275°F

- thermal movement at joints and cracks;
- deflections at joints and cracks;
- longitudinal surface profile;
- depth and shape of wheeltrack ruts;
- surface friction;
- surface texture.

In addition to the road condition measurements, traffic loading and the environmental conditions will be monitored although it is not proposed to install permanent weighscales or weather stations at the trial sites. The traffic loading will be determined from regular classified traffic counts using the relationships developed from research studies by Robinson (1988). Environmental conditions will be extracted from weather records from regional weather stations.

Equipment developed in the United Kingdom and not in general use in the United States is being used to record some of the road condition parameters. The high-speed survey vehicle will measure the longitudinal surface profile and surface texture. The transverse profilometer described by Potter and O'Connor (1990) will measure the depth and shape of wheeltrack ruts. The surface friction will be measured by the Sideway-force Coefficient Routine Investigation Machine (SCRIM).

Information Management System

Pavement data emanating from the trials will be transferred to the Information Management System maintained at the Transportation Research Board of the United States' National Research Council, located in Washington, DC. The data first will be entered into a copy of the system held at the University of Birmingham. During this stage, a number of validation checks will be performed. The second stage will be to transfer initially inventory data, then pavement monitoring data on a regular basis to the data base at the Transportation Research Board.

Several modifications to the copy of the Information Management System in the United Kingdom were necessary to accommodate data from the United Kingdom LTPP experiments.

This was due mainly to three areas of significant deviation from the LTPP specifications given in the *SHRP Data Collection Guide* (1990b):

1. differences in material types;
2. unit measurement standards;
3. equipment and test methods not included in LTPP specifications.

As a separate project, statistical analysis techniques are under development at the University of Birmingham to analyze the LTPP performance data collected in the United States for application in the United Kingdom. The approach uses engineering knowledge to guide the statistical derivation of the forms of the performance models. This will lead to more robust performance models that are based on engineering principles than if they were derived solely by statistical analysis.

Details of the Information Management System modifications and some preliminary analyses were presented at the Gothenburg Conference by Kerali and Potter (1991).

Conclusions

Three road trials have been constructed in the United Kingdom, and another is planned to study the long-term performance of bituminous overlays on jointed concrete pavements. These road trials are designed to complement and extend the SHRP SPS-6 and GPS-7B experiments.

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Appendix 4 Specific Pavement Studies and General Pavement Studies Design

The Specific Pavement Studies (SPS) program consists of eight experiments divided into four categories:

1. Structural Factors

   SPS-1: Strategic Study of Structural Factors for Flexible Pavements

   SPS-2: Strategic Study of Structural Factors for Rigid Pavements

2. Pavement Maintenance

   SPS-3: Preventive Maintenance Effectiveness of Flexible Pavements

   SPS-4: Preventive Maintenance Effectiveness of Rigid Pavements

3. Pavement Rehabilitation

   SPS-5: Rehabilitation of Asphalt Concrete Pavements

   SPS-6: Rehabilitation of Jointed Portland Cement Concrete Pavements

   SPS-7: Bonded Concrete Overlays of Concrete Pavements

4. Environmental Effects

   SPS-8: Study of Environmental Effects in the Absence of Heavy Loads

A fifth category of SPS experiments is being performed under the Asphalt program.

5. Asphalt Program-Related Study

   SPS-9: To evaluate or verify the test procedures and prediction models related to field performance factors for asphalts and asphalt-aggregates mixture analysis systems resulting from research findings in the asphalt program.

The General Pavement Studies (GPS) are a series of selected in-service pavement studies incorporating materials and designs which represent good engineering practice with strategic future importance. Nine pavement types are under investigation.

GPS-1	Asphaltic Concrete (AC) over Granular Base
GPS-2	AC over Bound Base
GPS-3	Jointed Plain Concrete Pavement
GPS-4	Jointed Reinforced Concrete Pavement
GPS-5	Continuously Reinforced Concrete Pavement
GPS-6A	AC Overlay of AC (Existing)
GPS-6B	AC Overlay of AC (Planned - Future)
GPS-7A	AC Overlay of Jointed Concrete Pavement (Existing)
GPS-7B	AC Overlay Jointed Concrete Pavement (Planned - Future)
GPS-9	Unbound Concrete Overlay of Concrete Pavement

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